A

DICTIONARY

OF

CHEMISTRY AND MINERALOGY,

WITH AN ACCOUNT OF THE PROCESSES EMPLOYED

IN MANY OF THE MOST IMPORTANT

CHEMICAL MANUFACTURES.

TO WHICH ARE ADDED A DESCRIPTION OF

CHEMICAL APPARATUS,

AND VARIOUS USEFUL TABLES OF

WEIGHTS AND MEASURES, CHEMICAL INSTRUMENTS, &c. &c.

ILLUSTRATED WITH FIFTEEN ENGRAVINGS.

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VOL. II.

LONDON:
PRINTED FOR JOHN AND ARTHUR ARCH, CORNHILL;
AND WILLIAM PHILLIPS, GEORGE YARD, LOMBARD STREET.
1807.

(W. PHILLIPS, PRINTER.)

SL NO. 085595

73058

ERRATA in Vol. II.

Page 30,	line 20 *from the bottom,*	*for* them, *read* it.
33,	3 *from the top,*	*for* urable, *read* durable.
58,	8 *from the bottom,*	*for* formed, *read* found.

J

JADE. See NEPHRIT.

JARGON. See ZIRCON.

JASPER.* Of this mineral there are, according to Werner, the four following subspecies.

1. *Subsp.* Egyptian Jasper, Egyptian Pebble. *Egyptischer Jaspis*, Wern. *Jaspe Egyptien*, Broch.

This Jasper always exhibits two or more colours in concentric zones or bands, more or less regular, with interspersed spots or dendritic figures. That part nearest the centre is almost always the lightest coloured, and is of a yellowish-grey passing into cream-yellow; the other colours that this mineral exhibits are chesnut and yellowish-brown, more rarely blood-red and brownish-red. It occurs in rounded pebbles or fragments, the surface of which is rough and dull. Internally it is glimmering. Its fracture is between flat conchoidal and splintery. Its fragments are indeterminately angular sharp-edged. It is very slightly translucent on the edges. Its hardness is somewhat inferior to that of quartz; it is brittle and easily frangible. Sp. gr. 2.5 6—2.6.

It is infusible before the blowpipe without addition.

It is found abundantly in Egypt and the adjoining desarts in rolled pieces along with other siliceous stones, constituting a breccia. From the soft tone of its colours and the high polish that it is susceptible of, it is applied to the same ornamental purposes as agate.

2. *Subsp.* Striped Jasper, Ribband Jasper. *Band Jaspis*, Wern. *Jaspe rubané*, Broch.

The colours which this mineral presents are pearl-grey, greenish and yellowish grey, yellowish and greenish white, ochre and Isabella yellow, flesh-red, blood and cherry red, and lavender-blue: they are arranged in bands or flame-shaped figures, or in veins or dots. It occurs in mass: is internally dull except where the admixture of foreign particles gives it a slight degree of lustre. Its fracture is conchoidal, sometimes approaching to splintery or earthy: its fragments are indeterminately sharp-edged. It is opake or slightly translucent on the edges. In hardness, frangibility, and specific gravity, it agrees with the preceding subspecies.

It occurs in large beds, and in Siberia seems to form entire hills. It is found abundantly and very beautiful in Siberia; also in Saxony, the Hartz, and Sicily. It receives a high polish, and is used for ornamental purposes.

3. *Subsp.* Porcellanite. *Porzellan Jaspis*, Wern. *Jaspe Porcelaine*, Broch.

The colours exhibited by this mineral are smoke-grey, yellowish and pearl-grey, lilac and lavender blue, orange and ochre yellow, straw, sulphur, and Isabella yellow, brick-red, blood and flesh red, yellowish and reddish brown, bluish and greyish black, and rarely mountain-green. It presents in general only one colour, but is sometimes spotted and clouded. The lavender-blue varieties often contain brick-red

* Emmerling, Widenmann, Brochant, Jameson.

vegetable impressions. It occurs in mass and in angular pieces, and is often cracked and rifty. It has a slight degree of internal lustre. Its fracture is imperfectly flat conchoidal, passing into uneven and earthy, sometimes also tending to slaty. It is opake, less hard than the preceding subspecies, very brittle, and easily frangible.

Before the blowpipe it melts *per se* into a black slag. Its constituent parts, according to M. Rose, are

Silex - - -	60.75
Alumine - -	27.25
Magnesia - -	3.
Oxyd of iron	2.5
Potash - -	3.66
	97.16

It forms beds in pseudo-volcanic hills, and is supposed to be argillaceous schistus altered by the combustion of beds of coal. It occurs plentifully in Bohemia.

This mineral seems to be placed among the jaspers with little propriety, being essentially distinct from them by its fusibility, hardness, and geological situation.

4. *Subsp.* Common Jasper. *Gemeiner Jaspis*, Wern. *Jaspe commun*, Broch.

The usual colours of this mineral are browns and reds of various shades, also lemon, ochre, and Isabella yellow. It exhibits in general only one colour, but is sometimes spotted, clouded, or striped.

It occurs massive and in rolled pieces. Internally it possesses a slight lustre between vitreous and resinous. Its fracture is conchoidal, passing into even and fine earthy. It is opake, sometimes slightly translucent on the edges. In hardness it nearly equals the first subspecies. It is brittle and easily frangible. Sp. gr. 2.3—2.7.

It is entirely fusible *per se* before the blowpipe.

It occurs in veins in primitive mountains, and in amygdaloid: it is also a constituent part of certain agate nodules, and in this state is called Jasper agate.

It is susceptible of a high polish, and is in considerable request for various ornamental purposes.

5. *Subsp.* Opal Jasper. *Opal Jaspis*, Wern. Its colours are reds and browns, rarely ochre yellow. The colour is uniform or disposed in dots, veins, and clouds. It occurs in mass. Internally it is shining with a lustre between vitreous and resinous. Its fracture is flat conchoidal. Its fragments are indeterminate and very sharp edged. It is opake but sometimes translucent on the edges. Is moderately hard, brittle, and easily frangible.

It is found in nests in porphyry near Tokay in Hungary, in the vicinity of Constantinople, and in the Kolyvan mountains in Siberia.

It is the connecting link between jasper and opal, and is distinguishable from the preceding subspecies, by the liveliness of its colours, its superior lustre, and constant conchoidal fracture.

JELLY. See GELATIN.

JET. See COAL.

JEW'S PITCH. See BITUMEN.

JUICES OF PLANTS. See SAP.

K

KALI. See CARBONAT of *Potash*.

KALKSPATH. } See LIMESTONE.
KALKSTEIN. }

KALZEDON. See CHALCEDONY.

KAOLIN. See CLAY *Porcelain*.

KARNIOL. See CHALCEDONY.

KATZENAUGE. *Cat's eye*, Kirw. *Oeil de Chat*. Broch.

Its principal colour is yellowish, greenish, or ash-grey; hence it passes into yellowish-brown, hair-brown, and hyacinth-red; it also sometimes exhibits olive or mountain green and greyish-black. When cut and polished it presents a peculiar play of light resembling the eye of the animal from which it takes its name.

It occurs in rounded and blunt-edged fragments not exceeding the magnitude of a nut. Internally it is shining with a resinous lustre. Its fracture is small and imperfectly conchoidal, passing into lamellar. Its fragments are indeterminately angular, sharp-edged. It is translucent, rarely semitransparent. Internally there may be observed small parallel white fibres, which are the cause of its peculiar play of light. It is hard and easily frangible. Sp. gr. 2.6.

By exposure to the heat of a porcelain furnace it loses its hardness, lustre, and transparency, and its colour becomes a pale grey. According to Saussure it is fusible, though with great difficulty, before the blowpipe.

It has been analyſed by Klaproth with the following reſults:

Silex - - -	95.	— 94.5
Alumine -	1.75	— 2.
Lime - - -	1.5	— 1.5
Oxyd of iron	0.25	— 0.25
	98.50	98.25

Of its geognoſtical ſituation nothing is known with certainty. It is brought to Europe from Ceylon and the Malabar coaſt. It is ſet in rings, and is in conſiderable eſtimation.

KEFFEKIL. See MEERSCHAUM.

KELP. See CARBONAT OF SODA.

KERMES *mineral* is the Hydroſulphuret of ANTIMONY.

KERMES. *Coccus Ilicis*, Linn. Alſo termed by the ancients *Coccus Scarlatinus*, *Granum Tinctorium*.

The Kermes is a ſmall inſect formerly much uſed in dyeing ſcarlet and different reds, and though its uſe is moſtly ſuperſeded at preſent by the cochineal, it is ſtill employed in ſome parts of Europe, and poſſeſſes very valuable properties as a dyeing material. The beſt kermes was formerly collected in Galatia and Armenia, but it is now chiefly procured from Languedoc in France, and from Spain and Portugal.[a]

The kermes lives on a ſpecies of prickly oak, the female inſect (which is the one uſed) grows to the ſize of a pea, and being of a round bulky form it was long miſtaken for the fruit of the tree, whence it was called grain of kermes, and the ſcarlet dye from it called by the French *Ecarlate de Graiu*.

This inſect hangs to the tree by a cottony down. About May or June it has acquired its full ſize, and is then gathered by hand, beginning generally about day-break. A perſon can collect from one to two pounds of it a-day. It is neceſſary to kill the inſect immediately, to prevent the hatching of the ova within its body, which is done by the vapour of vinegar.

When the living inſect is cruſhed it gives a red liquor, an agreeable ſmell, and taſtes bitter and ſharp. It gives a deep red tincture both to water and alcohol.

The colour given by this inſect to woollen cloth is extremely durable, but not ſo brilliant as that of cochineal. The colour does not take on ſilk. (*See the article* DYEING, p. 384.)

KIESELSCHIEFER.[a]

[a] Emmerling, Brochant, Jameſon.

This ſpecies is divided by Werner into the two following ſubſpecies.

1. *Subſp.* Siliceous Schiſtus, Kirw. *Gemeiner Kieſelſchiefer*, Wern. *Schiſte ſiliceux commun*, Broch.

Its principal colour is aſh-grey, bluiſh or greeniſh grey, with occaſional ſpots and ſtripes of red. It is often traverſed by veins of quartz. It occurs in maſs forming whole beds, or in ſmooth rounded pieces. Internally it is dull, rarely a little glimmering. Its fracture in the great is for the moſt part imperfectly ſlaty; in the ſmall is intermediate between ſplintery and uneven, inclining ſometimes to flat conchoidal. Its fragments are ſharp-edged, indeterminate. It is opake, occaſionally ſomewhat tranſlucent on the edges. It is hard, but not very difficult to break, and is moderately heavy.

Before the blowpipe it becomes white and friable. It occurs in thick beds for the moſt part among tranſition mountains; in Bohemia, Saxony, Swiſſerland, the South of Scotland, and Siberia, &c.

Siliceous ſchiſtus appears to have a conſiderable connexion with argillite, and is ſuppoſed by Wiedenmann to be only this ſubſtance hardened by containing a larger proportion than uſual of ſilex. It is one of the numerous rock maſſes on which the appellation Hornſchiefer has been beſtowed by the Germans, a name which has very properly been exploded by Werner.

2. *Subſp.* Lydian Stone. Touchſtone. *Baſanite*, Kirw. *Lidiſcherſtein*, Wern. *Pierre de Lydie*, Broch.

Its colour is greyiſh, paſſing into bluiſh-black. It occurs in maſs and in rounded fragments; and is generally penetrated by veins of Quartz. Internally it is glimmering. Its fracture is even, approaching to conchoidal and ſometimes to ſplintery: in maſs it is generally ſlaty. Its fragments are indeterminate and ſharp edged, often trapezoidal. It is opake, moderately hard, and eaſily frangible. Sp. gr. 2.4 to 2.8.

It is found in ſimilar ſituations with the preceding.

From its hardneſs and colour it is uſed as a touchſtone to aſcertain the comparative purity of the various kinds of gold and ſilver alloys.

Its black colour is affirmed by Humboldt to be cauſed by a portion of carbon.

KILKENNY COAL. See COAL.

KLINGSTEIN.[b] Wern. *Pierre ſonnante*, Broch.

[b] Jameſon, Brochant.

Its colour is dark greenish-grey, passing into yellowish and ash grey, or light olive-green or liver brown. It occurs in mass. The cross fracture is almost dull, the longitudinal fracture is glistening. The cross fracture is splintery, passing into conchoidal; the longitudinal fracture is more or less slaty. It breaks into indeterminate sharp-edged sometimes tabular fragments. In the great it often occurs in columnar masses. It is usually translucent on the edges. It is considerably hard, and not very easily frangible. When struck with a hammer it gives a ringing metallic sound, whence its name. Sp. gr. 2.57.

It melts easily before the blowpipe, and gives a clear almost colourless glass.

According to an analysis made by Klaproth[c] it consists of

Silex - - -	57.25
Alumine - -	23.5
Lime - -	2.75
Oxyd of iron -	3.25
——— manganese	0.25
Soda - - -	8.1
Water - -	3.
	98.1

According to Werner it belongs to the floetz trap formation; resting upon basalt, into which it frequently passes. It often contains crystals of felspar, and then forms slate porphyry. It is reckoned by Reuss to belong to the primitive rocks.

It occurs in the middle mountains of Bohemia; the Donnersberge in particular, near Milleschau, a conical mountain above 2500 feet high, consists entirely of this mineral. It has also been observed by Jameson in the island of Lamlash, in the Frith of Clyde. Very beautiful varieties of it also occur in rock masses between Lanberris and Caernarvon in North Wales.

KOHLENBLENDE. See COAL.

KRAGG. See BASALT.

KREIDE. See CHALK.

KREUTZSTEIN. See STAUROLITE.

KRISOBERIL. See CHRYSOBERYL.

KRISOLITH. See CRYSOLITE.

KRYSOPRAS. See CHRYSOPRASE.

KUNKELS PHOSPHORUS. See PHOSPHORUS.

KUPFER NICKEL. See NICKEL.

L

LABORATORY. (See the Appendix.)

LABRADOR-STONE. See Felspar.

LAC-(Gum.) *Lacque*, Fr.

Gum-Lac, as it is usually termed, is a substance properly neither a gum nor a resin, but a very singular compound which is prepared by the female of a very minute insect, the Coccus Lacca, which is found on a few species of trees in some parts of the East Indies, particularly on the Banyan Fig, and the Rhamnus Jujuba or Biher.[a b] The insect is nourished by the tree, fixing itself upon the twigs and extremities of the succulent branches, where also it deposits its eggs, which it glues to the branch by a red semi-pellucid liquid, the outside of which hardens in the air and also serves as a cell for the parent insect. This gradually increases, and when at its greatest size appears as an oval smooth red bag, full of a beautiful red liquid. When the eggs are hatched, the young insects appear first to feed upon the inclosed liquid, and after this is expended they eat through the investing coat, leaving a hollow red resinous bag which is the *Stick Lac*. The lac therefore appears in the economy of the insect to answer the double purpose of food and protection to the young animal, and when examined each bag is found to be in distinct cells like a honeycomb, but of different shape.

Lac is an article of great importance in many arts and in commerce. The best is procured from the province of Akam, but it is found in great abundance on the uncultivated mountains on each side of the Ganges.

The only trouble of collecting the rough or stick-lac is that of breaking down the branches and carrying them to market; but for the purpose of dying it is taken before the young insects have eaten their way through the bag, that is while the red liquor remains within it.

The best lac is of a deep-red colour, and the liquid within the cells has a sweetish taste, which in India is used immediately as a dye being miscible with water.

There are four kinds of lac known in commerce, namely—

1. Stick lac, which is the lac in its natural state, without any preparation.

[a] Kerr in Phil. Trans. vol. lxxi.

[b] Saunders in Phil. Trans. vol. lxxix.

2. Seed-lac, which is the former kind broken into small lumps, granulated and picked.

3. Lump-lac, which is seed lac liquified by fire.

4. Shell-lac, which is the cells of the stick lac, liquified by gentle heat, strained and formed into thin transparent laminæ in the following simple manner.

It is broken into small pieces and picked from the branches and sticks and put into a canvas bag. This is placed over the fire, and frequently turned till the lac is liquid enough to pass through its pores, when it is taken off and squeezed by two men in different directions dragging it along the convex part of a plantain tree prepared for the purpose. The degree of pressure on the plantain tree regulates the thickness of the shell.

Of the above three sorts of lac only the stick, shell, and seed lac are known in commerce.

There is besides a white or yellowish lac brought from Madagascar, highly resembling the pe-la of the Chinese, which has been very ably examined by Dr. Pearson, and will be presently noticed. *(See the next article.)*

The three species of common lac have lately been analyzed by Mr. Hatchett,[c] and the following is an abstract of the leading facts and of the general process.

When water is poured on the stick-lac coarsely powdered it soon begins to turn red, and by heating a crimson-coloured solution is obtained.

Shell-lac loses by this about 10 per cent. of its weight, and the undissolved residue becomes yellowish-brown.

Seed-lac loses about 3 per cent. and shell-lac no more than $\frac{1}{2}$ per cent.

The watery solution contains the colouring *extract*, one of the ingredients of lac, but does not extract the whole at once on account of its intimate union with the other constituent parts.

Alcohol dissolves a large portion of all the kinds of lac. When heat is not used the solution contains a part of the colouring extract, and a large quantity of a *resin* which may be separated from the solution by evaporation or by adding the solution to water, acidulated with muriatic or acetic acid and heating, when the resin will form a curdy coagulum. The portion soluble in *cold* alcohol, and which is entirely resin, except a little extract, amounts to about 68 per cent. from stick-lac, 88 per cent. from fine seed-lac, and 81 per cent. from shell-lac, but in the latter case about 10 more of resin remain mixed with the other ingredients. Hot alcohol dissolves also other parts of the lac which are not easily separable again.

Sulphuric ether dissolves less of lac than alcohol, and is not so useful in analysis.

Nitric acid digested with lac causes it to swell much and converts it to a brittle opake yellow substance, which more of the acid dissolves after 48 hours digestion. The solution poured into water separates some yellow flocculi which are found to be a kind of *wax*. The remaining liquor is of a bright yellow, contains neither oxalic nor malic acid, and by evaporation leaves a resinous matter again soluble in water. The alkalies separate nothing from this solution. This acid therefore operates too powerfully as a chemical agent, rather than a simple menstruum, to be very useful in mere analysis.

Muriatic and acetic acid digested on entire lac dissolve the colouring matter, and another substance closely resembling *gluten*, but they act but feebly and imperfectly on entire lac, these two substances being protected by the resin on which these acids have scarcely any action. This resin therefore should be previously separated by cold alcohol. The presence of gluten is most conspicuous in shell-lac, pieces of which, after the action of alcohol, retain their figure, become more bulky, elastic, and nearly white. This led Mr. Hatchett to suspect of the presence of caoutchouc, but from the circumstance that boiling water destroyed its elasticity, it was obvious that this substance was not caoutchouc but gluten.

Potash and soda, and carbonat of soda, completely dissolve all kinds of lac, and carbonat of potash partially. About $\frac{1}{5}$ of the weight of carbonat of soda is sufficient. These solutions are saponaceous and purple. By repose a scum or cream rises to the surface, which is part of the wax, and the remainder may be separated by acids.

Lac therefore is found by these experiments to consist of a colouring extract of resin, gluten, and wax, all of them in intimate combination, but separable almost entirely by a judicious order and selection of the different re-agents.

The general properties of each of these ingredients are the following:

1. The extract when dry is of a deep crimson; soluble chiefly but not totally in water, hot or cold; less so in alcohol, but the residue after the action of alcohol dissolves in water; insoluble in ether; partially soluble in muriatic and acetous acid, giving a red liquor which is changed

[c] Phil. Transf. for 1804, p. 191.

to purple by alkalies; is totally soluble in acetic acid; and equally so in the alkalies. When pure alumine is put into the aqueous solution, and a few drops of muriatic acid added, a beautiful coloured lake is precipitated. A fine precipitate is also formed by muriat of tin.

2. The resin is brownish yellow, soluble in alcohol, ether, acetic acid, nitric acid, potash, and soda, and is precipitable by water from all these solvents except the two last.

3. The gluten is obtainable in two ways: if the pieces of lac after digestion in alcohol be digested with dilute acetic or muriatic acid, most of the gluten is dissolved, and may be precipitated by alkalies added in due proportion; but is redissolved by an excess of them, and then is separable by acids. It much resembles the gluten of wheat.

4. The wax is found floating like oil on the solution of lac after long boiling in nitric acid, which takes up every thing else, and congeals when cold; or it may be more easily procured, by first digesting the lac with cold alcohol, and treating the residuum with boiling nitric acid, which will separate the wax.

Thus obtained it is white, of the consistence of bees wax, melts at a less heat than boiling water, and burns with a white flame and smell like spermaceti. It is insoluble in cold alcohol, but with a boiling heat a portion is dissolved, most of which separates by mere cooling, and the remainder by affusion of water. Potash boiled with the wax forms a milky solution, but the chief part of the wax floats at the top, and seems to be converted into a kind of soap, hardly soluble, and inflammable. Acids separate the remainder of the wax from the alkaline solution.

Ammonia dissolves a small portion of the wax; nitric and muriatic acid none. This wax bears the strongest analogy with the wax of the Myrica or Candleberry Myrtle. (*See the article Wax.*)

Stick lac was analyzed by Mr. Hatchett in the following way.

A. 200 grains were repeatedly digested in boiling water, and the red solution evaporated, left 18 grains of extract.

B. The residue of the last process was digested in repeated portions of alcohol, without heat for forty-eight hours, and these solutions evaporated, gave 136 grains of resin.

C. The residue of the last was again digested in boiling water, and 2 grains more of extract were obtained.

D. The residue of the last was boiled with one ounce of muriatic acid, with two of water, and the solution saturated with carbonat of potash which gave a precipitate of 11 grains when dry, which was gluten.

E. The residue from the last consisted of wax entangling bits of twigs and other accidental impurities. Part of it was separated by melting and straining through linen, and the remainder was boiled with potash. The whole wax thus obtained was 12 grains, and 13 grains of the impurities remained.

The shell lac was analysed in a more complex way, the resin and wax being more intimately united in this species of lac than the others, and on account of its texture not being reducible to fine powder. The processes A. B. C. D. being repeated as in the last, the residue was digested some days in the cold, in three ounces of acetic acid, after which half a pint of alcohol was added, and the whole heated, whereby the wax was separated in a very pure state. The aceto-alcoholic tincture which was brown was then poured into water, which became milky, and being heated and filtered, more resin separated in a curdy form. The remaining clear liquor was then saturated with carbonat of potash, and a further portion of gluten was obtained.

The three different species of lac being analyzed, gave the following proportions: 100 parts of stick-lac gave 68 of resin, 10 of colouring extract, 6 of wax, 5.5 of gluten, and 6.5 of extraneous substances: 100 parts of seed-lac gave 88.5 of resin, 2.5 of extract, 4.5 of wax, and 2 of gluten: 100 parts of shell lac gave 90.9 of resin, 0.5 of extract, 4. of wax, and 2.8 of gluten.

Lac is employed for a variety of purposes in the arts, both in India and elsewhere.[4] The finer pieces of shell-lac are cut into ornaments of various kinds, such as beads and necklaces; the shell-lac enters largely into the composition of sealing wax, and hard japans or varnishes, hence called *lacquers*, and lac is also used for dyeing. For this last the stick-lac is the only kind employed, as the colouring matter chiefly resides in the extract, of which the shell-lac contains a very small proportion, but on the other hand as this has much more resin, it is greatly preferable for varnishes and lacquers. A composition of rough angular sand melted with lac is much employed in India as the material for grindstones, which are cast into a circular shape, and when well managed, they cut very fast. The lapidaries use corundum

[4] Kerr.

powder instead of sand, and form with lac a composition for grinding and polishing gems.

LAC (*White*). } A white or yellowish-
LACCIC ACID. } white waxy matter, the production of insects, and called in Madras *White lac*, was first particularly noticed by Dr. Henderson about the year 1786, and supposed by him to resemble very closely the *Pe-la* of the Chinese, or white wax used in varnishes, for candles, &c. Some of this white lac sent over to England about the year 1793, was examined by Dr. Pearson with the following results.[*]

The white lac is in grey, opake, rough, roundish pieces, of about the size of a pea. It has a saltish and bitterish taste, but when fresh gathered it appears from Dr. Anderson's account to have a sweetish and delicious flavour. On pressing the pieces between the fingers, a saltish liquid oozes out. White lac has no smell unless when rubbed. After melting and straining it sinks in water.

When heated in water it melts at 145°, and then a reddish liquid separates from the lac and mixes with the water. This liquid has the following properties. It gives instantly a red colour to litmus; its specific gravity is 1025; its taste is saltish but not sour. Evaporated considerably it deposits small needle-like crystals mixed with a slimy sediment. The liquor on distillation gives a clear fluid which dissolves chalk and carbonat of soda with effervescence, and in so doing it becomes neutralized, and no longer turns litmus red. By heat the whole of this substance is volatilized and destroyed, giving only the common products of animal matter. From its reddening litmus and neutralizing the alkaline and earthy carbonats, this substance is inferred to be an acid, and from its destructibility by heat it probably belongs to the class of animal or vegetable acids, but it does not accurately agree with any of the other acids in all its properties. It is therefore either some known acid modified in its chemical properties by union with some other part of the lac, or else it is a peculiar acid to which the term *laccic acid* may be given.

The whitish lac remaining after the acid or saline liquid has been thoroughly separated by washing was of the colour of bees-wax, and hard and brittle as rosin. On digesting it with solution of potash, Dr. Pearson found that it became brown, gave a smell like palm-oil, and united with the alkali to a coagulated mass, but could not be brought to the state of a true soluble soap. The solution was decomposed by acids. Ammonia had nearly the same effect as potash. Candles were made of this substance with cotton wicks, which burned rapidly, and gave much smoke and a resinous smell. In this respect it differs from the Chinese pe-la, which burns as well as the finest wax, and with as little smoke.

When the white lac was heated with nitric acid much nitrous gas was given out, and a perfect solution was obtained, but on cooling nearly the whole separated, quite white, scarcely any being found to remain in the acid liquor. The hot nitrous solution also gave a copious precipitation when poured into water. This lac was totally dissolved in five parts of oil of turpentine, but the solution grew turbid as it cooled. Ether dissolved a tenth of its weight of this lac, but imperfectly. Alcohol dissolved by repeated affusion all but 15 per cent. of this lac; the hot saturated solution became opake and thick by cooling, but when spread on paper it did not leave a bright and smooth varnish.

By various other experiments this lac appeared to have the greatest chemical analogy with bees-wax, though it differed from it in a few particulars.

If obtained largely it probably might prove of much use in the arts.

LAC SULPHURIS is sulphur separated by acids from its alkaline solution. It is somewhat altered in the process, and changes its lemon-yellow colour for a grey or yellowish-white like cream.

It is thought to be somewhat milder as a medicine. (*See* SULPHUR.)

LACTIC ACID. See MILK.

LAKES. A lake may be defined to be an intimate combination of colouring extract, with an earth or metallic oxyd formed by precipitation from the solution of the colouring matter. Thus if a solution of alum is added to an infusion of madder a mutual decomposition takes place, and part of the alumine falls down intimately united with the colouring matter of the madder. This separation is much assisted by an alkali.

The lakes form some of the beautiful pigments, and are much used in water-colour painting and other purposes. They are almost invariably composed either of alum, or sometimes the solutions of tin, and some other watery solution of a colouring matter. The most important are described under the articles *Carmine*,

[*] Phil. Trans. vol. lxxxiv.

Cochineal, *Madder*, *Brazil-Wood*, and fome other of the colouring materials.

LAMP-BLACK. There are two fpecies of lamp-black in common ufe; one is the light foot from burning wood of the pine and other refinous kinds, and the other is a heavy black prepared from bones by calcining them in *clofe* veffels.

(For the former kind fee the articles CHARCOAL and TURPENTINE, and for the latter the article BONE. Ivory-black is of the fame fpecies with that from bone.)

LAPIS CALAMINARIS. See CALAMINE.

LAPIS INFERNALIS. See LUNAR CAUSTIC.

LAPIS LAZULI. *Lazurftein*, Wern. *Pierre d'Azur*, Broch.

The colour of this mineral is Pruffian-blue, fmalt-blue, or fky-blue. It occurs in mafs, diffeminated, or in rolled pieces. It poffeffes a faint-glimmering luftre. Its fracture is fine grained uneven. Its fragments are indeterminately angular. It is generally tranflucent on the edges. Its hardnefs is fuperior to that of glafs. It is brittle and eafily frangible. Sp. gr. 2.76 to 2.94.

It effervefces flightly with acids when pulverized. Before the blowpipe it lofes its colour and runs into a whitifh enamel. When calcined, and then treated with the mineral acids, it forms with them a gelatinous mafs. When heated it becomes phofphorefcent. A low red heat does not impair its colour. It has been analyzed by Klaproth,[a] and appears to confift of

Silex	-	46.
Alumine	-	14.5
Carbonat of lime	-	28.
Sulphat of lime	-	6.5
Oxyd of iron	-	3.
Water	-	2.
		100.0

This beautiful mineral is faid to be found in a vein accompanied by garnet, felfpar, and pyrites, near the lake Baikal in Siberia. It is alfo found in Chinefe Tartary. Alfo in Perfia, Bucharia, and the Ifland Hainan in the Chinefe fea. It generally occurs mixed with felfpar, quartz, and iron pyrites, which laft was formerly miftaken for fpecks and fpangles of native gold.

From its colour, and the high polifh that it is capable of receiving, it is ufed in various ornamental work, fuch as inlaying, feal-ftone &c. It is alfo highly valued by painters, affording that beautiful and permanent, but e penfive pigment, ultramarine blue.

LAPIS LYDIUS. See KIESELSCHIEFER

LAPIS OLLARIS. See POTSTONE.

LAVA. *Lave*, Broch.

The colour of lava is greyifh or greenif black, greenifh-grey, or yellowifh-grey. It fpotted externally reddifh or yellowifh brow yellowifh-white, or fulphur-yellow. It occu porous, carious, or veficular. Its luftre vitreous, more or lefs gliftening. Its fractu is imperfectly conchoidal, paffing into fi grained uneven. It is flightly tranflucent the edges. Is moderately hard, brittle, eafi frangible, and light. It generally attrac ftrongly the magnetic needle. It is eafily fu ble into a black compact glafs.

It generally inclofes other foffils, efpecial cryftals of felfpar, augite, hornblende, and le cite.

It is the product of Etna, Vefuvius, Hec and other volcanoes.

On account of its lightnefs it is much e ployed in building; and when difintegrated the action of the air forms a foil of remarkal fertility.

LAVA GLAS. See CHALCEDONY.

LAZULITE. *Lazulith*, Wern. *Lazulit* Broch.

The colour of this mineral is a deep fma blue. It occurs diffeminated in fine grains maffes of the fize of a hazle-nut. The latt often prefent the appearance of fhort tetral dral prifms. Its fracture is uneven with glimmering luftre. It is opake, paffing tranflucent. When pulverized it has a bluif white colour. Its hardnefs is nearly equal that of quartz. It is brittle, and eafily frangib

At a red heat it lofes its colour and becon grey. It is infufible *per fe* before the blowpi but with borax runs into a clear yellow gla It is with difficulty acted on by the acids, and colour is unalterable by cauftic alkali, at t common temperature. It contains, accordi to Klaproth, filex, alumine, and oxyd of ir but neither carbonat nor fulphat of iron.

It occurs at Vorau in Auftria, mixed w quartz, and forming a fmall vein in micace fchiftus.

LAZULITE (of Hauy). See LAPIS LAZU

LAZURSTEIN. See LAPIS LAZULI.

LEAD. *Plumbum*, Lat. *Plomb*, Fr. *B* Germ. *Saturnus*, Alchem.

[a] Analyt. Eff. I. p. 168.

Lead is a metal of a bluish-grey colour, is malleable, ductile, and inelastic: it is very soft, is fusible at less than a red heat, is easily oxydable by exposure to the air when melted, and its oxyd is easily fusible into a transparent yellow glass.

§ 1. *Ores of Lead.*

Sp. 1. Galena.

Of this there are the two following subspecies.

1 *Subsp.* Common Galena.* *Gemeiner Bleiglanz*, Wern. *Galène*, Broch. *Plomb Sulfuré*, Hauy.

Its colour is a more or less perfect lead-grey, inclining in some varieties to blackish; it sometimes presents superficially an iridescent tarnish. It occurs in mass, disseminated or investing; also in particular shapes, such as globular, reniform, specular, reticulated, cellular, cylindrical, &c. also crystallized.

The primitive crystalline form of galena is the cube, besides which it presents the following varieties.

1. The cube with its solid angles replaced by triangular planes.
2. The cube elongated and its solid angles replaced by pentagonal planes.
3. The perfect octohedron.
4. The preceding with the edges replaced by long pentagonal planes.
5. The octohedron with the solid angles doubly truncated.
6. The octohedron singly truncated on the solid angles, and doubly or trebly truncated on the edges.

The crystals are rarely large, but generally middle-sized or small; either grouped one upon the other, implanted, or solitary. Their planes are commonly smooth, sometimes drusy, rarely carious or rough. The external lustre of galena varies, according to its surface, from resplendent and specular to glimmering. Internally it varies from specular to glistering, and its lustre is metallic. Its fracture is lamellar, either plane, curved, or divergent; this latter passes into radiated, the rays being short and broad. It is divisible in a three-fold rectangular direction, hence its fragments are cubical. When in mass it is often composed of granular and rarely of lamellar distinct concretions. It is soft, somewhat sectile, easily frangible. Sp. g. 6.56 to 7.78.

Before the blowpipe it decrepitates, then melts, giving out a sulphureous odour, and when this ceases a globule of metallic lead remains behind.

Galena consists essentially of lead and sulphur in the proportion of about 100 of the former to 15 of the latter, but besides these ingredients, iron pyrites, grey antimony, copper, gold, and silver, are found in various proportions, besides different earthy ingredients, chiefly lime and silex. The following are some of the most recent and accurate analyses that have been made of this ore.

	From Kirschwald, in Deux Ponts.	Kampfstein.	Ecklerberg.	Kantenbach.	Cologne.
Lead	54.	69.	68.69	64.	63.1
Sulphur	8.	16.	16.18	18.	12.
Carbonated lime and silex	38.	15.	16.13	18.	19.67
Oxyd of iron	0	0	0	0	3.33
	100	100	101	100	98.1

The above analyses were made by Vauquelin, to which we shall subjoin an analysis of galena from Durham, by Dr. Thomson.

Lead	85.13
Sulphur	13.02
Oxyd of iron	0.5
	98.65

The proportion of silver in galena varies greatly, from $\frac{1}{100}$ or less to $\frac{1}{12}$; it is observable that the presence of this metal considerably impairs the lustre of galena, and that it is much more frequently found in the octohedral than in the cubical varieties of this mineral. The presence of antimony is commonly indicated by a tendency to the radiated fracture.

It is next to pyrites the most common of metallic ores, and is found in beds and veins in primitive, transition, and secondary mountains. It occurs most abundantly in argillaceous schistus and secondary limestone, and is almost always accompanied by blende and calamine. To enumerate the places where it is

* Emmerling, Lenz, Hauy. Brochant, Kirwan, Jameson.

found, would be to mention almoſt all the mineral diſtricts that are known: we ſhall content ourſelves therefore with pointing out the principal mines of this ſubſtance in Britain.

Theſe are ſituated in Cornwall, Devonſhire, and Somerſetſhire; in Derbyſhire, in Durham, and the contiguous boundaries of Lancaſhire, Cumberland, and Weſtmoreland; in Shropſhire, in Flint and Denbighſhire, in Merioneth and Montgomeryſhire; at the lead-hills in Scotland on the borders of Dumfriesſhire and Lanarkſhire, in Ayrſhire, and at Strontian in Argyleſhire.

Moſt of the lead of commerce is procured from this ore; it is alſo made uſe of without any further preparation as a glazing for coarſe pottery.

2. *Subſp.* Compact galena. *Bleiſchweiſ*, Wern. *Galène compacte*, Broch.

Its colour is ſimilar to but generally ſomewhat lighter than that of the preceding ſubſpecies. It occurs in maſs, diſſeminated and ſpecular (the ſpecular in Derbyſhire is known by the name of *ſlikenſide*). The ſpecular variety is ſplendent externally, the others are only glimmering. Internally all the varieties are ſlightly gliſtening with a metallic luſtre. Its fracture is even, paſſing into flat conchoidal. Its fragments are indeterminately angular. It acquires a poliſh by friction; is more tender than the preceding ſubſpecies, and agrees with it in the reſt of its characters. Sp. gr. 7.44.

In its habitudes with the blowpipe it differs from common galena in not decrepitating on the firſt application of heat.

It occurs in veins with common galena, and always occupies the ſides of the vein. It is not very common.

Sp. 2. Triple Sulphuret of Lead.[c]

Its colour is dark grey inclining to black. It occurs cryſtallized. Its primitive figure is a rectangular tetrahedral priſm, beſides which it preſents the following varieties.

1. The primitive cryſtal with the ſolid angles replaced by triangular planes.
2. The ſame with its lateral edges replaced by rectangular planes, forming an eight-ſided priſm.
3. The ſame terminated by a very low and deeply truncated tetrahedral pyramid.
4. Four priſms with deeply truncated dihedral ſummits joined to each other at their baſes, forming a rectangular croſs.

The planes correſponding with the lateral faces of the original priſm are longitudinally ſtriated, the others are ſmooth. The cryſtals are large and middle-ſized, with a ſplendent metallic luſtre both externally and internally. Its fracture is coarſe-grained uneven. In hardneſs it ranks between calcareous and fluor ſpar; is very brittle and eaſily frangible. It leaves a faint black trace when rubbed on paper. Sp. gr. 5.76.

When ſuddenly heated before the blowpipe it crackles and ſplits, but if gradually heated it melts, and on cooling forms a globule of a dull metallic-grey colour; by further expoſure to the flame a white and ſomewhat ſulphureous vapour is diſengaged, conſiſting of ſulphur and antimony, and there remains behind a cruſt of ſulphuretted lead, incloſing a globule of metallic copper. It has been analyzed by Mr. Hatchett with the following reſult.

17.	Sulphur.
42.62	Lead.
24.23	Antimony.
12.8	Copper.
1.2	Iron.
97.85	
2.15	Loſs.
100.	

It has hitherto been found only in the mine Huel-Boys, in Cornwall.

Sp. 3. Blue Lead Ore. *Blaubleyerz*, Wern. *Mine de Plomb bleue*, Broch.

Its colour is intermediate between lead-grey and indigo-blue; it alſo paſſes ſometimes to ſmoke-grey and black. It occurs ſometimes in maſs, but uſually cryſtallized in ſmall ſix-ſided priſms, perfectly equiangular, often a little bulging, and the external ſurface of which is ſomewhat rough and dull. Internally it poſſeſſes a feebly-glimmering metallic luſtre. Its fracture is even, paſſing into fine-grained uneven and flat conchoidal. Its fragments are indeterminately angular. It is opake, gives a ſhining metallic ſtreak, is ſoft, ſomewhat ſectile, and eaſily frangible. Sp. gr. 5.46.

It fuſes readily before the blowpipe, then burns with a weak blue flame, giving out a penetrating ſulphureous vapour, and is reduced to a metallic globule.

It has not been regularly analyzed. Klaproth diſcovered in it ſome phoſphoric acid, and the other conſtituent parts are probably ſulphur and oxyd of lead.

It has hitherto been found only at Zſchoppau

[c] Phil. Tranſ. 1804; p. 30.

in Saxony, in veins accompanied by black and brown lead ores, carbonat of lead, malachite, quartz, fluor ſpar, and heavy ſpar.

Sp. 4. Carbonat of Lead. *Weiſs Bleyerz*, Wern. *Mine de Plomb blanche*, Broch.

Its colour is greyiſh or yellowiſh-white, yellowiſh-grey, cream-yellow, and light clove-brown, ſometimes though rarely dark aſh-grey. It occurs maſſive, diſſeminated, and ſuperficial; but moſt frequently cryſtallized. Its primitive figure is a rectangular octohedron, diviſible parallel to the common baſe of the two pyramids of which it is compoſed. The chief varieties of cryſtallization that it exhibits are,

1. The cuneiform octohedron.
2. The pyramidal dodecahedron.
3. The preceding with a ſix-ſided priſm interpoſed between the pyramids.
4. The ſame as var. 3. with ſummits of the terminal pyramids replaced by a ſix-ſided plane.
5. A ſix-ſided priſm with the ſummits compoſed of four planes, the oppoſite ones being equal and ſimilar.
6. The ſame with the ſummits compoſed of ſix planes, the correſponding ones being equal and ſimilar.

The cryſtals are uſually ſmall, rarely middle-ſized, either ſolitary or in groups: their ſurface is generally ſpecular and ſplendent, ſometimes a little rough or ſtriated, and then only gliſtening. Internally its luſtre varies from highly reſplendent to gliſtening, and is that of the diamond, inclining on the one hand to ſemi-metallic, and on the other to reſinous. Its fracture is ſmall conchoidal, paſſing into fine-grained uneven and fine ſplintery or imperfectly fibrous. Its fragments are indeterminately angular. It varies from tranſparent to tranſlucent, and is in a remarkable degree doubly refracting. It is ſoft, brittle, and eaſily frangible. Sp. gr. 6.0 to 7.2.

Before the blowpipe it decrepitates, becomes yellow and then red, and if heated on charcoal is immediately reduced. It effervesces ſlightly in cold nitrous or muriatic acid, but more vigorouſly if the menſtruum is warmed. It is blackened by hydroſulphuret of ammonia. It is often confounded with columnar heavy ſpar, but may be readily diſtinguiſhed from this by its ſuperior ſpecific gravity and its habitudes with the blowpipe and hydroſulphuret of ammonia. There are ſeveral analyſes of this ore, but perhaps the moſt ſatisfactory are the following.

From Zitterfeld, by Weſtrumb.		From Lead-hills, by Klaproth.	
Oxyd of lead	81.2	77	Lead
Carbonic acid	16.	5	Oxygen
Oxyd of iron	0.3	16	Carbonic acid
Lime - - -	0.9	2	Water and loſs
	98.4	100	

Carbonat of lead is almoſt always accompanied by galena, and appears to be more frequently found in argillaceous ſchiſtus than in any other kind of rock. It is by no means a rare mineral, but ſeldom occurs in ſufficient quantity to be worth ſeparating from the adhering ſpar, &c. for the purpoſe of ſmelting. The fineſt ſpecimens of this ore that are found in Britain come from the mines of Derbyſhire, of Lead-hills in Scotland, and Minera in Denbighſhire, at which laſt place the compact variety is remarkably abundant.

Sp. 5. Black Lead Ore. *Schwartz Bleyerz*, Wern. *Mine de Plomb Noir*, Broch.

Its colour is greyiſh-black paſſing into ſmoke-grey. It occurs in maſs, diſſeminated or cellular, or cryſtallized in ſix-ſided priſms, either ſimple or terminated by dihedral ſummits.

The cryſtals are ſmall and grouped confuſedly in druſes. Their ſurface is ſometimes ſmooth, ſometimes ſtriated longitudinally. Externally it is ſplendent or ſhining. Internally it is ſhining or gliſtening, with a luſtre approaching to ſemi-metallic. Its fracture is fine-grained uneven, paſſing into imperfectly conchoidal. Its fragments are indeterminately angular. It is opake, or at moſt tranſlucent on the edges. It gives a greyiſh-white ſtreak; it is moderately hard, brittle, and eaſily frangible. Sp. gr. 5.77.

Before the blowpipe it decrepitates, and is quickly reduced to a metallic globule. It has recently been analyzed by Lampadius, and appears to conſiſt of

72.	Lead
7.	Oxygen
18.	Carbonic acid
2.	Carbon
99	

It occurs in veins of galena, principally of the moſt recent formation. It uſually occupies the upper part of the vein, incruſting galena, and being itſelf covered by carbonat or green

phosphat of lead. It is found in the Lead-hills in Scotland; in Bohemia and Saxony; in Brittany in France, and in Siberia.

Sp. 6. Muriat of Lead.[b] *Corneous Lead Ore,* Jameson. *Hornblei,* Karsten.

Its colour varies from the palest grey to wine-yellow. It occurs crystallized in cubes, either simple or terminated by tetrahedral pyramids, or bevelled on the edges. The crystals are middle-sized and small, and have a splendent vitreous lustre. The principal fracture is foliated, the cross fracture conchoidal. It is transparent or semi-transparent. It is much softer than carbonated lead; and is easily frangible. Sp. gr. 6.05.

When heated on charcoal before the blowpipe it runs into an opake orange-coloured globule, which on cooling becomes first yellow and then white. At a high heat the globule suddenly spreads over the charcoal, the acid flies off in vapours, and there remain behind minute grains of metallic lead.

It has been analyzed by Klaproth and Mr. Chenevix with the following results.

85.5	——	85	Oxyd of lead
8.5	——	8	Muriatic acid
6.0	——	6	Carbonic acid
100.0		99	

It has hitherto been found only at Matlock in Derbyshire, upon galena.

Sp. 7. Brown Phosphat of Lead. *Braun Bleyerz,* Wern. *Mine de Plomb brune,* Broch.

Its colour is hair-brown, passing on one side into grey, and on the other into clove-brown. It occurs rarely in mass, but generally crystallized in lengthened six-sided prisms, sometimes so slender as to become capillary. The surface of the crystals is blackish and rough: internally it is glistening, with a resinous lustre. Its fracture is small grained uneven passing into fine-splintery. Its fragments are indeterminately angular. It is more or less translucent, gives a white powder, is soft, moderately brittle, and easily frangible. Sp. gr. 6.6 to 6.9.

Before the blowpipe it melts very easily, but is not reduced to the metallic state; by cooling concretes into a radiated mass. It does not effervesce with acids.

According to Klaproth it consists of

Oxyd of lead - -	78.58
Phosphoric acid -	19.73
Muriatic acid - -	1.65
	99.96

It occurs in veins at Huelgoet in Brittany, at Miess in Bohemia, near Schemnitz in Hungary, Saska in the Bannat, and Zschoppau in Saxony.

Sp. 8. Green Phosphat of Lead. *Grün Bleyerz,* Wern. *Mine de Plomb verte,* Broch.

Its usual colour is olive-green, but it also exhibits several other shades of green, such as grass-green, greenish-white, pistachia, and yellow green, whence it passes into sulphur-yellow. It occurs sometimes in mass, or reniform or botryoidal, but most commonly crystallized.

Its primitive form is the pyramidal dodecahedron, consisting of two six-sided pyramids joined at their bases. The varieties of crystallization which it has been found to exhibit are

1. The regular hexahedral prism.
2. The same, with the lateral edges replaced by rectangular planes, thus forming a dodecahedral prism.
3. The hexahedral prism terminated at each extremity by a hexahedral pyramid.
4. The same with the apex of the terminating pyramid replaced by a hexagonal plane.

The crystals are generally small and very small, either solitary or in groups. Sometimes the crystals are so minute as to appear like a fine down.

The surface of the crystals is smooth and shining; internally they are glistening, with a resinous lustre. The fracture is small-grained uneven, verging sometimes upon splintery. Its fragments are indeterminately angular. It is translucent, very rarely semi-transparent. Its hardness is superior to that of carbonated lead; it gives a greenish-white powder, is brittle, and easily frangible. Sp. gr. 6.2 to 6.9.

Before the blowpipe it becomes of a greyish-white and melts very easily, without decrepitation, into a globule; but shows no signs of reduction. If the globule is cooled slowly it forms a polyhedral striated solid. It is soluble difficultly, and without effervescence in the mineral acids.

The three subsequent varieties of this mineral have been analyzed by Klaproth with the following results.

[b] Nicholson's Journal, 4to. iv. p. 219. Klapr. Analyt. Ess. ii. p. 111.

Yellowiſh-green phoſphat, from Zſchoppau.	Graſs-green phoſphat, from Hoffsgrund in the Briſgau.	Lemon-yellow phoſphat, from Wanloch-head.	
78.	77.1	80.	Oxyd of lead
18.37	19.	18.	Phoſphoric acid
1.7	1.54	1.62	Muriatic acid
0.8	0.1	0.	Oxyd of iron

A ſpecimen from Erlbach on the other hand was found by Vauquelin to contain

45.18	Lead
18.7	Phoſphoric acid
4.05	Oxygen
32.	Silex
99.93	

This mineral is found in veins both in primitive and ſecondary mountains, but chiefly in the former of theſe. It is accompanied for the moſt part with galena, carbonat of lead, and iron ochre, with quartz, heavy ſpar, and calcareous ſpar.

It is met with in Bohemia, Saxony, Bavaria, the Briſgau, France, Scotland, and Siberia.

Sp. 9. Sulphat of Lead. *Blei Vitriol,* Wern. *Vitriol de Plomb natif,* Broch.

Its colour is greyiſh or yellowiſh-white, paſſing into ſmoke and aſh-grey. It has been found only cryſtallized. Its primitive figure is an octohedron, compoſed of two tetrahedral pyramids with rectangular baſes; the other varieties are

1. The cuneiform octohedron.
2. The ſame with the long ſides of the common rectangular baſe replaced by two hexagonal planes.
3. The ſame as var. 2, with the edges of the pyramids adjacent to the common baſe replaced by ſecondary four-ſided planes.
4. A very ſhort eight-ſided priſm terminated by ſummits of eight planes placed upon the correſponding ſides of the priſm.

Externally the cryſtals are ſmooth and ſhining; internally they are ſplendent with a vitreous luſtre. The fracture of this mineral is compact. It is more or leſs tranſparent paſſing into tranſlucent. It is ſoft, ſomewhat brittle, and eaſily frangible. Sp. gr. 6.3.

Before the blowpipe it decrepitates on the firſt application of the flame, but when previouſly pulverized it melts into a brilliant ſcoria, which by continued ignition on the charcoal is reduced to metallic lead. It has been analyzed by Klaproth with the following reſults.

From Angleſey.	From Wanloch-head.	
71.	70.5	Oxyd of lead
24.8	25.75	Sulphuric acid
2.	2.25	Water
1.0	0.	Oxyd of iron
98.8	98.5	

It occurs in veins of galena at Wanloch-head, and in the province of Andaluſia in Spain, and in a bed of cellular quartz with iron pyrites and iron ochre at Parys mine in Angleſey.

Sp. 10. Arſeniat of Lead.

Of this there are two ſubſpecies.

1. *Subſp.* Reniform Arſeniat. *Bleiniere,* Karſten.

The colour of the recent fracture is browniſh-red, but by expoſure to the air it paſſes into ochre and ſtraw-yellow. It occurs in reniform maſſes, the ſurface of which is rough and uneven. Internally it is gliſtening with a reſinous luſtre. Its fracture is conchoidal. It occurs in coarſe-granular diſtinct concretions; is opake; gives a dull orange-yellow ſtreak; is ſoft and brittle. Sp. gr. 3.92.

Before the blowpipe it melts, emits an arſenical odour, and at length is converted into a black ſhining globule, in which grains of lead are obſervable.

According to an analyſis by Bindheim it conſiſts of

35.	Oxyd of lead
25.	Arſenic acid
1.5	Silver
14.	Iron
7.	Silex
3.	Alumine
10.	Water
95.5	

It has hitherto been found only at Nertſchinſk in Siberia.

2. *Subſp.* Green Arſeniat of Lead.

Its colour varies from meadow-green to wax-yellow. It occurs in needles, in fine filaments, in compact maſſes, and granular concretions.

Its lustre varies from silky to resinous. It is translucent, moderately brittle, and easily frangible. Sp. gr. 5.04.

Before the blowpipe it gives out an arsenical vapour, and is reduced to a metallic globule.

It occurs in veins with galena in Andalusia in Spain, and in the department of the Saone and Loire in France.

The arsenico-phosphat of lead of Hauy may probably also be referred hither. Its colour is yellowish-green; it occurs in mamillary masses, studded with brilliant points. Before the blowpipe it gives out an arsenical odour. It contains, according to Fourcroy, by whom it has been analysed,

50	Oxyd of lead
29	Arsenic acid
14	Phosphoric acid
4	Oxyd of iron
3	Water
100	

It is met with in a mine at Rosiers in Auvergne.

Sp. 11. Molybdat of Lead. See MOLYBDENA.

Sp. 12. Chromat of Lead. See CHROME.

Sp. 13. Lead Ochre. *Bleyerde*, Wern. *Plomb terreux*, Broch.

Of these there are two subspecies.

1. *Subsp.* Indurated.

Its colour is yellowish or greenish-grey, straw-yellow, apple-green, smoke-grey, and light brownish-red. It occurs in mass. Internally it is glimmering or glistening, with a resinous lustre. Its fracture is fine-grained uneven, passing into fine splintery and earthy, also into flat conchoidal. It is opake or at most slightly translucent on the edges. It gives a brownish streak; is soft, passing into friable; is not very brittle, but is easily frangible.

It is reducible before the blowpipe, effervesces with acids, and is blackened by hydrosulphuret of ammonia.

It occurs with the other ores of lead, and is usually accompanied by iron pyrites and malachite.

2. *Subsp.* Friable.

Its colour is yellowish-grey approaching to sulphur-yellow. It occurs massive, disseminated, and superficial. It is composed of dull, dusty, friable particles; is meagre and rough to the touch, and is heavy.

It is found to accompany galena and the other ores of lead, and is found at Wanlochhead and the Lead-hills in Scotland, in the Hartz and Saxony, in Poland, and Siberia.

§ 2. *Smelting and Reduction of Lead Ore.*

The only ore of lead that is wrought in the large way is galena, and the method of treating this is very simple, partly on account of the richness of the ore and partly on account of the low price of the metal itself, which therefore will not admit of any but the most summary methods of bringing it into a marketable state.

The ore when first brought up from the mine is *dressed* by women and boys, who with a hand-hammer separate the greater part of the adhering impurities, consisting of blende, iron pyrites, quartz, calcareous spar, &c. The residue being broken into pieces about the size of a hazle-nut is washed from all adhering clay and dirt, and is then ready to be smelted. The furnace used for this purpose is the common reverberatory with a low arch. A ton or more of the ore is spread on the floor of the furnace, and by means of the flame from pitcoal it is quickly brought to a bright red heat. In this situation it is occasionally stirred with iron rakes to expose fresh surfaces to the action of the flame and facilitate the separation of the sulphur. In a short time the mass begins to acquire a pasty consistence; upon which the heat is lowered and the ore is kept at a dull red till the sulphur is nearly all got rid of; the fire being then increased the ore is brought to a state of perfect fusion, and visibly consists of two fluids; the lower is the metallic lead, the upper is a vitreous slag, still holding a considerable portion of lead but mixed with various impurities. In this state of the process the fire is damped and a few spadefuls of quicklime are thrown into the fluid mass; by this the scoriæ are suddenly solidified, and are raked to the side of the furnace; the tap-hole is then opened, and the lead runs into moulds placed to receive it, where it congeals into oblong masses called *pigs*, weighing about 60 lbs each. As soon as the lead has run out of the furnace, the tap-hole is closed, the scoriæ are replaced in the bed, and being quickly raised to a glowing red heat are soon melted; the greatest part of the lead that they contained by this means collects into a mass at the bottom; a little lime is thrown in as before, the scoriæ thus rendered solid are raked aside, and the lead which they covered is let off into a mould. This second scoria, though still holding from 5 to

8 per cent. of lead, is now removed from the furnace, and applied to no purpose but that of mending roads, the expence of separating the last portions of metal being more than the value of the produce.

The lead of the first running is the best; that procured from the scoriæ being sensibly harder, and less malleable on account of the iron that it contains.

It is a matter of doubt among the most intelligent smelters whether there is any advantage in retaining the carbonat of lead, with which the galena is very often mixed in considerable proportion. On the one hand it is certain that it contains a large quantity of metal, and in assays is very easily reducible; but on the other hand, when treated in the reverberatory it vitrifies almost at the first impression of the heat, and being a very active flux it is apt to bring the whole into fusion while much sulphur still remains unsublimed; hence the amount of scoriæ is prodigiously increased, and with it the trouble of the smelters, while the produce of lead is very little augmented.

§ 3. *Assay and Analysis of the Ores.*

The analysis of the ores of lead is upon the whole extremely simple. In general the moist way is the most accurate.

Before giving the individual processes the general methods may be mentioned whereby lead is separated from the other metals with which it is usually combined in the different ores, and the data on which it may be estimated in analysis.

Lead is readily separated from silver by making a solution of both in nitric acid, and adding muriatic acid as long as any precipitate appears. The silver falls down in the form of luna cornea, and with it a quantity of muriat of lead, and if the mixture stands some hours undisturbed, this latter salt also forms needled crystals on the surface of the luna cornea. All the silver falls down in this manner, but part only of the lead, and the muriat of lead is separated from the luna cornea by boiling water, 22 parts of which will dissolve 1 of muriat of lead, but not a particle of the muriat of silver. The solution of the muriat of lead is still more easily effected by digesting in dilute nitric acid, which dissolves it readily, but not the luna cornea.

Lead is separated from bismuth by dissolving both to saturation in nitric acid, either concentrated, or diluted with no more than a fourth of water, and then pouring the concentrated solution into a large quantity of water. The oxyd of bismuth then separates as a heavy white powder, and the lead remains dissolved. Some bismuth however remains, but to the solution may then be added a saturated solution of sulphat of soda, which will precipitate the lead only in the form of a white pulverulent sulphat of lead, the composition of which will be presently mentioned. But where all the bismuth is to be obtained for the purpose of analysis, and not merely to be separated from the lead, it is better after the bismuth has first pecipitated, to add muriatic acid to the clear solution, which will throw down the silver, if there be any, and also some muriat of lead, mixed with some of the bismuth that remains in the solution, and which last if redissolved in nitric acid, will again be decomposed by water as before. The whole muriat of lead may then be dissolved in water and nitric acid, and converted into a sulphat by means of sulphat of soda as before.

Lead is separated also from iron and copper by dissolving both in nitric or muriatic acid, and adding sulphat of soda to precipitate the lead. If the nitric acid be used, some of the oxyd of iron will first precipitate as a brown red ochre, which should be removed.

The same method will separate lead from tin, cobalt, and zinc.

The composition of the sulphat of lead artificially formed in these processes, has been given with some small variation by different chemists; Klaproth estimates it as follows.

100 parts of sulphat of lead, *dried at a low red heat*, are composed of 73.96 of oxyd of lead and 26.04 of sulphuric acid, and the above oxyd of lead is composed of 69.44 of metallic lead, and 4.52 of oxygen. This is not the only state of oxygenation of which lead is capable, but it is that in which, according to Klaproth, it is inferred to exist in all the native salts and oxyds of this metal hitherto analysed.

It must be observed however, that this calculation gives a much lower state of oxygenation than is found by other experiments, as will be noticed presently, and the estimation of the quantity of metallic lead is made by other chemists, and even in other experiments of Professor Klaproth, to rise as high as about 71 per cent. Mr. Hatchett reckons it to be 70.9.

But where the muriat of lead is free from other admixture, the quantity of metal may be estimated without converting it into a sulphat, by the following data: 100 parts of lead dissolved in nitric acid, and decomposed by dropping in muriatic acid as long as any turbidness

enfused, and evaporated to perfect dryness (but short of volatilization of any part of the combined muriatic acid) produced 133 of muriat of lead, and consequently 100 parts of dry muriat of lead indicate 75.2, nearly, of metallic lead, and (if oxygenated in the same degree as in the sulphat) 4.89 of oxygen, or 80.09 of oxyd of lead.

The muriat of lead may also be reduced by dissolving it in water and immersing a rod of iron, whereby the lead will be precipitated in the metallic state in fine lamellæ.

Some of the analyses of the individual lead ores may now be mentioned.

Vauquelin analysed a galena from Cologne in the following way.[a]

A quantity was roasted slowly and lost 12 per cent. of sulphur in the process. Another quantity was heated with very dilute nitric acid, which gave a smell of sulphuretted hydrogen, and dissolved all the metallic part. The undissolved residue heated to redness, parted with its sulphur, and 16.67 per cent. of silex was left. The nitric solution was then decomposed by sulphat of soda, and the sulphat of lead collected and weighed. The proportion of metal it contained (estimating 100 of the sulphat to be equivalent to 75.72 of metal) was 63.1 per cent. The liquor was then saturated with ammonia, which deposited 3.3 of oxyd of iron, and lastly carbonat of potash threw down 3 of carbonat of lime.

In the dry way the galena after roasting may be mixed with thrice its weight of black flux, covered with salt, and melted, when a button of reduced lead will be found at the bottom, which will also contain the silver and other metals, if present.

The triple sulphuret of lead, antimony, and copper found in Cornwall, was thus analysed by Mr. Hatchett.

Two hundred grains were put into a matrass with 2 ounces of muriatic acid, and heated, and nitric acid was added drop by drop, till the whole moderately effervesced. It was then gently heated for an hour, and a green solution was formed, on which floated a quantity of sulphur, which was collected, digested separately with a little muriatic acid, and then washed and dried. It weighed 34 grains, and afterwards burned away in a red hot earthen cup, without residue, and therefore was pure. The solution, with the muriatic acid in which the sulphur had been washed, was boiled, and then mixed with 6 pints of boiling distilled water, which it rendered instantly milky, and was filtered while hot, and the filter washed with more boiling water. The white precipitate left on the filter, when dried on a sand bath, weighed 63 grains, and was oxyd of antimony. The liquor with the washings deposited on cooling some crystallized muriat of lead. It was evaporated nearly to dryness, and a few drops of sulphuric acid added to the liquor left, to separate in the form of a sulphat, what little of the lead remained in solution. The residue was then redissolved in boiling water, and decomposed entirely by sulphat of soda, and the sulphat of lead thus produced, (added to the former portion) was washed and dried on a sand bath, and weighed 120.2 grains.

The liquor which was now blueish-green, was rendered of a deep blue by ammonia, and a small quantity of oxyd of iron separated, which when dried and heated with wax, became magnetic, and weighed 2.4 grains.

The liquor was then evaporated nearly to dryness, boiled with a strong lixivium of potash till nearly dry, and on washing with water, some black oxyd of copper was left weighing 32 grains after thorough drying.

In the above analysis the metals are estimated as in their metallic state, this being the state in which they exist in the sulphurets, and hence, for the 63 grs. of oxyd of antimony, 48.46 of the regulus are to be put down, and for the 120.2 of sulphat of lead, the author estimates 85.24 of metallic lead, which is in the proportion of 70.9 in 100.

The carbonat of lead was analysed by Klaproth in the following way: 100 grains were dissolved in a mixture of 200 grains of nitric acid with 300 of water, and the loss of weight by the effervescence noted, which amounted to 16 grs. and was carbonic acid. The nitric solution was then diluted, and a cylinder of zinc immersed, which precipitated the lead in the metallic state in beautiful vegetations. This washed and dried, weighed 77 grains, equivalent to 82 of oxyd, as it is in this state that the lead exists in the ore. This proportion however, would give an increase of only 6.5 of oxygen upon 100 of lead.

That rare variety of lead ore, the compound carbonat and muriat of lead, has been analysed both by Klaproth and Chenevix. By Klaproth,[b] the following method was pursued: fifty grains of the ore were rubbed with 150 of very pure carbonat of potash, (previously freed from every muriat) and heated in a platina crucible to a

[a] Journ. des Mines, No. 68.

[b] Essays Vol. 2.

moderate redneſs, then lixiviated and filtered. An oxyd of lead was left behind. The ſolution was ſlightly ſuperſaturated with nitric acid and precipitated with nitrat of ſilver. The muriat of ſilver thus obtained weighed 27 grains, equal to more than 4 of concrete muriatic acid. Another quantity of the ore of 100 grains was then powdered and nitric acid affuſed, which produced an efferveſcence of carbonic acid. This ſolution gave with nitrated ſilver 55 grains of luna cornea, correſponding very cloſely in proportion with the former experiment, the acid of which amounted to 8.5 grains. The lead was then precipitated by *cauſtic* potaſh and the oxyd thus procured weighed, after thorough drying, 85½ grains, which is the ſtate of oxygenation in which it is ſuppoſed to exiſt in the ore. In this caſe, therefore, 85.5 grains of oxyd of lead were combined with only 8.5 of muriatic acid which is far ſhort of the ſaturating quantity, ſince in the artificial cryſtallized muriat of lead the proportion of acid amounts to 13 or 14 per cent. This deficient ſaturation therefore allows the preſence of carbonic acid, which amounts to 6 grains, and completes the ſaturation of oxyd.

A ſimilar ore was analyzed by Mr. Chenevix,* nearly in the ſame way and with the ſame reſult. The ore was firſt diſſolved in nitric acid, and the quantity of carbonic acid, amounting to 6 grains, eſtimated by the loſs after efferveſcence. The ſolution was then neutralized by ammonia, and tried by different teſts. As nitrat of lime gave no precipitate, the ſolution could not contain either the arſenic or molybdic or phoſphoric acids, and as nitrat of barytes gave none, the abſence of ſulphuric acid was proved.

Nitrat of ſilver was then added and a copious precipitate enſued, and the luna cornea weighed after drying 48 grains, which Mr. C. eſtimates as equivalent to 8 of muriatic acid. The compoſition of the ore is thus ſtated: 6 grains of carbonic acid ſaturate 34 of oxyd of lead, and 8 of muriatic acid ſaturate 51 of oxyd of lead, and the acids may be ſuppoſed to be in the ſtate of perfect ſaturation, conſequently the ore is compoſed of 59 muriat of lead and 40 of carbonat of lead; or of 14 of acid and 85 of oxyd.

The Angleſea ſulphat of lead was thus analyzed by Klaproth: 100 grains were firſt ignited moderately and loſt 2 grains, which were water of cryſtallization. The remainder was mixed with 400 grains of carbonated potaſh, and kept for ſome time in a red heat in a platina crucible, which gave a reddiſh-yellow hardened maſs. This, digeſted with water, was all diſſolved except the oxyd of lead ſeparated in the previous proceſs, amounting to 72 grains, after ſtrong drying. This oxyd was rediſſolved in nitric acid, and depoſited thereby one grain of oxyd of iron. The ſolution was then decompoſed by zinc, and yielded 66.5 grains of metallic lead. The alkaline fluid formed by the waſhing of the contents of the crucible, after ignition, was then ſaturated with nitric acid and acetate of barytes added as long any ſulphat of barytes was precipitated. This amounted to 73 grains, equal to 24.8 of concrete ſulphuric acid on the eſtimation that 100 parts (after ignition) contain 34 of acid. The iron in this ore appears merely caſual.

The phoſphated lead ores have been alſo examined by the ſame eminent chemiſt with much attention. The compoſition of all the varieties is very uniform, all conſiſting of phoſphoric acid and oxyd of lead, together with muriatic acid, the quantity of which varies very little. It is a diſtinguiſhing and ſingular property of the phoſphat of lead, that when melted into a round bubble under the blow-pipe it aſſumes a regular polygonal garnet-ſhaped form on the moment of ſolidifying by cooling.

The green phoſphat was thus analyzed: after ſome imperfect attempts at reduction in the dry way, 100 grains of the ore were diſſolved in hot nitric acid leaving no reſidue. Nitrat of ſilver then gave a precipitate of 11 grains of luna cornea, the muriatic acid of which amounted to 1.7 grains. Sulphuric acid was then added to the warmed ſolution, by which ſulphat of lead was precipitated, weighing after ignition 106 grains, equal to 73.61 of metallic lead or 78.4 of the oxyd. The liquor was then freed from the exceſs of ſulphuric acid by nitrat of barytes, it was then nearly ſaturated with ammonia, and acetite of lead added. The phoſphoric acid in the ſolution was then precipitated in the form of phoſphat of lead, weighing, after ignition, 82 grains, of which the mere acid amounts to 18.37 grains. The reſt of the ſolution was then mixed with a little muriatic acid, inſpiſſiated by evaporation, and alcohol added to rediſſolve the muriat of iron then formed, if any, from which by the addition of pruſſiat of potaſh there was obtained an extremely ſmall blue precipitate, indicating no more than about .1 of a grain of oxyd of iron.

In another experiment the phoſphoric acid,

* Phil. Journ. 4to. vol. iv.

instead of being engaged with lead, was saturated partly by soda, partly by ammonia, and by due evaporation and cooling, crystals of the microcosmic salt, or the phosphat of soda and ammonia were obtained. The other varieties of this phosphat were analyzed in the same way.

With regard to the analysis of the molybdat of lead the reader is referred to the article *Molybdena*, and to *Chrome*, for the Chromat of lead. Those ores in which lead is only a small part of the metallic contents will be described under the other metals as silver, bismuth, &c.

The compound of oxyd of arsenic, lead, and iron, examined by Lelievre and Vauquelin[b], gave the following appearances: 100 parts roasted for half an hour, with a little suet added occasionally to favour the evaporation of the arsenic, lost 38, and became black and magnetical. The remaining 62 parts boiled in muriatic acid made a red solution, giving out much oxymuriatic acid gas, and crystallized muriat of lead was deposited. This solution evaporated, redissolved in water, and decomposed by sulphat of soda, gave 25 of sulphat of lead, equal to 20.2 of lead or 22 of the oxyd. The residue, saturated with ammonia, gave 39 parts of oxyd of iron.

The analysis of lead ores in the dry way is attended with much more loss of the metallic contents, especially when alkaline fluxes are used, all of which act more or less on this oxyd.

LEAD is a metal of a blueish-white colour, almost silver-white when recently melted, but very soon tarnishes. It gives a peculiar smell when rubbed or heated. Its specific gravity, according to Brisson, is 11,352. It is very malleable, readily extending under the hammer into very thin leaves, but its tenacity is less than that of any other metal, for a wire $\frac{1}{10}$ of an inch in diameter will break with a weight of 30 lbs.

Lead is the least sonorous of all the metals, giving when struck a very flat heavy sound. It melts long before being red-hot. The melting point of this metal has been variously given, owing to the known irregularity of the mercurial thermometers at very high temperatures.

Morveau gives it at 590° Fahr. According to Mr. Crichton it is 612°. When slowly cooled it crystallizes in quadrangular pyramids. Heated fully to redness it smokes and sublimes in the open air, giving a grey oxyd, which settles on the sides of the vessel that contains it, or if in large quantity mixes with the atmosphere around and collects in the chimnies of the furnaces where it is melted. Lead in all forms and combinations is poisonous when taken in any quantity, and a frequent exposure to its vapour, or much handling it, gradually produces dangerous bowel-complaints, paralytic symptoms, and other maladies.

Though the surface of lead at a common temperature soon tarnishes, this metal will remain exposed to air and all weathers for a great length of time without further change, the oxidated surface protecting the inner part from destruction, and hence the durability of leaden roofs, pipes, &c. but yet in process of time the whole is corroded throughout.

Water has but little direct action on this metal either hot or cold, not being decomposed by it as it is by iron and some other metals; but it slowly assists the action of the air, for lead will be corroded sooner in a damp than in a dry atmosphere.

When lead is melted in free exposure to the air, it becomes almost immediately covered with a wrinkled pellicle of a dirty grey colour, and if this is skimmed off others form in succession, till the whole metal is changed into a yellowish-grey oxyd, the weight of which was one of the earliest observations made on the effect of calcination in increasing the weight of metals.

This grey oxyd, by a further continuance of heat with constant stirring, passes through various shades of a greenish-yellow to a deep dun-yellow, owing to a successive absorption of oxygen. The highest state of oxygenation to be produced by mere calcination, appears to be that in which the oxyd has a beautiful high red colour, with more or less scarlet, when it is called *Minium* or *Red Lead*, a substance well known as a pigment, and especially as a flux in glass-making, for which it is largely employed.

Minium, however, cannot be made with any certainty in the small way by mere calcination in the air, however long this is continued, the colour of the oxyd never rising higher than a dun yellow; it is only produced in manufactories in the large way, with frequent stirring. The process for making red lead is thus described by Dr. Watson[c] as carried on in Derbyshire.

The furnace is very much like a baker's oven with a low vaulted roof, and on each side of the furnace are two party-walls rising from the floor of the surface but not reaching to the roof. In the interval between these

[b] Phil. Mag. vol xvi.

[c] Essays, vol. iii.

walls and the sides of the furnace the coal is burned and the flame draws over the top of the party-walls, and striking the roof is thence reflected down upon the surface of a quantity of lead which is laid on the floor of the furnace. The metal soon melts, and instantly becomes covered with a pellicle which is successively raked off till the whole is changed into a greenish-yellow powder. This is taken out, ground in a mill, and washed, to separate the portion of lead that still remains in the metallic state, by which it becomes an uniform yellow colour, and is then thrown back into the furnace and constantly stirred, so that every part may be equally exposed to the action of the flame, and in about forty-eight hours of calcination it is converted into *red-lead*.

Some practical nicety is required in the management of the fire, which if too slack gives only a yellow or orange coloured powder, and if too fierce makes the minium dusky and destroys that brilliant gloss for which it is so much admired. There are besides other minuter circumstances of management, and probably kept secret as much as possible. Jars[d] mentions in particular that of cooling the minium when made very gradually, and closing all the openings of the furnace, otherwise the beauty of colour is much impaired. Some makers also sprinkle the surface with water occasionally during the calcination.

In Holywell minium is made from litharge, which saves the previous calcination.

A portion of the lead in the process of conversion into minium is always lost by volatilization, part of it being dissipated in the air and another part settling in the chimnies and on the roofs of the furnace, in the form of a yellowish-white soot, with crystallized lumps intermixed, which is collected from time to time, and either reduced into lead or is mixed with the lead in the subsequent calcination. The quantity of this sublimate collected, according to Watson, is about $\frac{1}{400}$ of that of the minium produced, but of course must vary greatly. On this account, and from the loss by entire volatilization in the air, it is impossible to ascertain directly the full increase of weight which the lead should acquire by conversion into minium. The actual increase is on an average about a tenth, twenty hundred weight of lead producing twenty-two hundred of minium.

It has been mentioned that the oxyd of lead becomes yellow before it turns red. The substance called *Massicot*, and used as a yellow pigment is generally made of this yellow oxyd, but the finer sorts are said to have an addition of muriat of ammonia, and to be therefore a muriated oxyd of lead, or approaching to that fine pigment called the Naples yellow, which will be afterwards noticed.

Litharge is another of the oxyds of lead made by the simple action of heat and air. It is produced in the process of extracting the SILVER from lead, as will be more fully described under that article. The silver-holding lead is put in a large shallow dish made of ashes, and therefore very porous, and is kept till red-hot in a wind-furnace, at the back of which enters the pipe of large bellows that direct a blast of air on the surface of the red-hot metal. This converts it into a scaly yellowish-white glistening oxyd, which is raked off successively to expose new surfaces, till nearly the whole of the lead is thus changed into litharge. There are slight variations in the colour of litharge, some kinds having more of a silvery gloss, others being of a dull red-yellow. Part of it is again reduced into very pure and soft lead, and the rest is selected for sale. The waste of lead by volatilization is many times more in reducing lead into litharge than into minium, so that, though there is a large gain of oxygen from the air, the litharge weighs less than the lead from which it was produced. Part of it, however, is lost by soaking into the test, a porous vessel in which it is made.

All the oxyds of lead, when strongly heated to a full redness, very readily run into a glass which has a clear topaz-yellow colour, and is the most powerful flux known of every vitrifiable matter, so that, in a very short time, the vitrified oxyd corrodes all the common crucibles and runs through them like a sieve, and even the closest porcelain can only retain it for a time. Minium in vitrification always gives out a quantity of oxygen gas, but the quantity varies much, even in the same sample, and is never so much as 8 per cent. During the vitrification a portion of the minium is spontaneously reduced to the metallic state, and is found at the bottom of the crucible. A fuller account of the vitrifying power of the oxyds of lead will be found under the article *Glass*.

The above oxyds of lead, namely massicot, minium, and litharge, do not appear to have been accurately analyzed with a view to ascertain their metallic contents in the dry way by simple reduction, but the following examination of them, and the other salts and oxyds of lead,

d. Voyage Metall.

by Dr. Thomson, in the moist way, will give some information concerning their composition.[e]

Minium loses no sensible weight at a heat of 400°. In several experiments to ascertain the loss by fusion, no agreeing result could be obtained, the loss varying from 4½ to 7 per cent. The common minium of the shops always contains some impurities, generally sand, and also an alloy of antimony, and a minute portion of silver.

When red lead is digested in nitric acid a part is dissolved and the rest is converted into a brown powder that remains at the bottom of the vessel. The lead in solution is found by other experiments (to be presently mentioned) to be in the state of oxygenation in which the oxygen forms 9.5 per cent. or as the *yellow* oxyd; whilst the insoluble residue is superoxygenated in the proportion of 20 per cent. a separation of an uniform substance into two others with opposite characters, being by no means uncommon in chemical phenomena. By estimating the total of oxygen in the more and the less oxygenated portion, Dr. T. concludes, that minium is composed of about 88 of lead to 12 of oxygen.

Litharge analyzed by the same chemist lost at a red heat about 4 per cent. of its weight. It dissolves in nitric acid *with effervescence*, and consequent loss of 4 per cent. of weight, which may be reckoned to be carbonic acid. By precipitating the solution with a carbonated alkali and other experiments, Dr. T. states the composition of litharge to be about

$$\left.\begin{array}{r} 86.9 \text{ lead} \\ 9.1 \text{ oxygen} \end{array}\right\} 96 \text{ yellow oxyd}$$

$$4 \text{ carbonic acid}$$

$$\overline{100.}$$

According to the above analysis therefore minium is more highly oxygenated than litharge, but the latter contains a quantity of carbonic acid, which minium does not. It is singular, however, how this difference with respect to carbonic acid arises, since the heat at which each oxyd is made does not appear to differ materially, and certainly, of the two, minium is that which is much more directly exposed to the action of carbonic vapour, owing to the reverberation of the coal flame on its surface, during so many hours in the manufacture.

It has been mentioned that lead, when kept in fusion exposed to the air, first becomes changed to a dusky-grey powder with a greenish tinge. This has been considered by some chemists as lead in the first state of oxygenation, but Professor Proust has properly observed,[f] that it is only a mixture of the yellow oxyd with particles of metallic lead, whence the green colour from the mixture of the yellow of the former with the blue of the latter. This opinion is confirmed by the fact, that in the first part of the process of making red-lead the dusky-green powder is separated by mere washing, into *yellow* oxyd and the blue-black particles of metallic lead, the latter subsiding soonest in the water. The *yellow* oxyd therefore appears as far as hitherto known to be in reality the first state to which lead is reduced by calcination in the air.

But Professor Proust asserts that an oxyd with a less proportion of oxygen (and at the minimum of oxydation) may be formed by boiling the nitrat of lead on metallic lead, whereby the oxygen of the nitrat is compelled to distribute itself equally over a much greater quantity of lead, and the acid forms with this new oxyd a brilliant yellow scaly salt, very soluble, but the proportions of which have not yet been determined. On this subject Dr. Thomson has the following experiments: 100 grains of nitrat of lead were dissolved in water and boiled with a cylinder of clean bright lead. The metal soon lost its brilliancy, became covered with a white crust, and the liquid became yellow. When all action appeared to have ceased, the cylinder was taken out, and was found to have lost 44 grains. But the whole of this was not dissolved, for a *bluish-grey powder* began to collect during the boiling, and increased as long as the cylinder of lead continued to be acted on. As the solution cooled it deposited the yellow scaly crystals mentioned by Proust, which salt has the following properties: the taste is sweet and astringent, like the common nitrat, but it is less soluble in water; when cautiously heated to redness it melts into a yellow mass, losing thereby 18.5 per cent. of its weight, which are acid and water of crystallization, and 81.5 of a *yellow oxyd* remains. This oxyd redissolved in nitric acid, and crystallized yields 117. of common nitrat of lead. But 117 of common nitrat are found by separate experiments to contain about 81.5 of yellow oxyd, and hence it would appear that this salt is not a nitrated *sub-oxyd* of lead but a *subnitrat* of lead, or in other words the degree of oxygenation of the lead is the same in both, but the difference consists in the relative pro-

[e] Phil. Journ. 8vo. vol. viii.

[f] Journ. de Phys. tom. lvi. p. 206.

portion of nitric acid. A similar proof of this was also deduced from the decomposition of this yellow salt by carbonat of potash, both in the moist and the dry way, and a sub-nitrat extremely similar was formed simply by heating the common nitrat to expel only part of its acid, as will be presently noticed. It does not appear however that Dr. T. examined the *blueish-grey powder* produced by boiling lead with nitrat of lead, which therefore deserves a further examination.

The *yellow oxyd* of lead is that which appears to be the basis of by far the greater number of the salts of this metal, and therefore is of primary importance. It is formed in the calcination of this metal *per se*, and is formed at so early a period that it is probably the first change that this metal undergoes by union with oxygen, though, as already mentioned, the colour is not obvious at first, on account of being mixed with metallic lead finely attenuated, and not yet oxygenated, which debases the colour to grey or yellowish-green, till it is separated by washing. *Massicot* is the yellow oxyd, as pure as it can be formed by mere calcination, but as this is changed to *minium* by continuing the process, the yellow oxyd made by heat can never be procured so uniform as by solution.

If lead be dissolved in nitric acid, the solution crystallized, the crystals dissolved in water, and precipitated by carbonat of potash, a white carbonat of lead is produced, which heated in a retort gradually to redness, parts with its carbonic acid and water, and the pure yellow oxyd is left.

The proportions of these substances given by Dr. Thomson are the following: 69 grains of lead form 112 of the solid nitrat (dried at 300°) which produce 90 of the carbonat, which is reduced by ignition in a retort to 77 of the yellow oxyd. Therefore 77 of this oxyd contain 69 of lead and 8 of oxygen, or per cent. 89.7 of lead and 10.3 of oxygen. But Proust gives the composition of the yellow oxyd to be 91 of lead and 9 of oxygen.

But Klaproth found that 100 parts of lead dissolved in dilute muriatic acid,[g] precipitated by caustic potash, and the oxyd washed and briskly dried till it began to turn yellowish, amounted to 115 grains, which would give the proportions of 86.78 of lead to 13.22 of oxygen. It is impossible to reconcile these results in a satisfactory manner without further experiments.

The yellow oxyd may also be obtained by direct calcination of the nitrat in close vessels till every thing volatile is driven off, by which the remaining oxyd melts into a hard yellow opake glass,[h] but this mode will not give the proportions with accuracy, as some of the lead is totally reduced in the process, and is found diffused in globules in the substance of the glass.

There is yet another oxyd of lead to be noticed, which is the *brown oxyd*.

In this the lead is at the highest state of oxygenation. It was first discovered by Scheele, and many of its distinguishing properties noticed by him. It is procured by adding nitric acid to minium. The experiments of Scheele are the following:[i]

If finely powdered minium be dissolved in nitrous acid, diluted with a triple quantity of water, a black or brown powder remains which is the oxyd in question. This is not soluble in the acid by itself, but on adding a little sugar a clear solution is immediately obtained. The same happens with dilute vitriolic acid. If muriatic acid be poured on the black powder an effervescence takes place when warmed, and a strong smell of aqua regia (oxymuriatic acid) rises, the powder becomes white, and is turned into common white muriat of lead. If the oxyd be distilled by itself in a glass retort, it grows yellow and becomes in every respect similar to the common yellow oxyd of lead, and is then entirely soluble in nitrous acid, and no longer gives any smell of oxymuriatic acid.

To these accurate observations of this excellent chemist it may be added, that in calcination *per se* it gives off much oxygen gas during its conversion to the yellow oxyd, which Dr. Thomson estimates at 9 per cent. of the weight. In insolubility in nitric acid it resembles the black oxyd of manganese, in which also sugar effects a solution by depriving the oxyd of a portion of its oxygen. The same effect is produced by adding reguline lead to the acid and minium, by which also a solution is obtained,[k] and then none of the brown oxyd is formed, or if already formed it again disappears. We may conclude therefore that minium is too much oxygenated to be entirely dissolved without heat in nitric acid, but when these substances come in contact, an unequal partition of oxygen takes place, one portion absorbing oxygen from the other, and becoming thereby the brown oxyd, and the other by the loss of oxygen passing to the state of yellow oxyd and dissolving in the acid, and hence the nitrous solution standing over the brown oxyd gives a yellow

[g] Essays, vol. i. p. 539. [h] Thomson. [i] Essays on Manganese. [k] Chenevix.

precipitate with alkalies, like the common nitrat of lead. The oxymuriatic acid gas passed through water and minium, also causes one portion to be dissolved, and converts the other to the brown oxyd.[l]

This oxyd is a tasteless powder of a flea-brown colour, very fine and light.[m] As 100 grains lose 9 of oxygen by heating, and become converted thereby into yellow oxyd, Dr. T. concludes that it is composed of 91 of yellow oxyd (containing 9.4 of oxygen) and 9 of oxygen, and hence 100 parts of it contain 81.6 of lead and 18.4 of oxygen. Professor Proust makes the proportion of oxygen to be 21 per cent. Whichever calculation is taken it is unquestionably in the highest degree of oxygenation that lead is known to assume; minium, the next in order, containing not more than 12 per cent.

To the above observations on the oxyds of lead may be added in this place the composition of the artificial white carbonat produced by decomposing any salt of lead by a carbonated alkali. According to Dr. Thomson 112 grains of nitrat of lead (containing 69 of reguline lead) produce by solution in water, and decomposition by carbonat of potash, 90 grains of the white carbonat when dried at 300°. These 90 grains, when heated slowly to redness, part with 13 grains, which are water and carbonic acid, and 77 grains of yellow oxyd remain. Hence 100 grains of carbonat would produce 85.5 grains of yellow oxyd, the metallic part of which would be 76.6 grains, and the oxygen 8.9.

It may be of use to recapitulate all the oxyds and carbonated oxyds of lead in the supposed order of oxygenation, (beginning with the lowest) with their leading properties, premising that it is a subject in which there are still many points of uncertainty which it would not be very difficult for future experiments to clear up.

The sub-oxyd stated by Proust to be formed by boiling the nitrat of lead with reguline lead. The existence of this is doubtful.

The yellow oxyd presumed to be the basis of most of the salts of lead, particularly the common nitrat from which its proportions have been deduced. It is produced either by heating minium till it no longer gives out oxygen, or by calcining the solid nitrat (in both of which cases it is mixed with reduced lead) or more accurately by heating the white carbonat nearly to melting, or by decomposing the salts of which it is the basis by caustic alkali. It gives *no* oxygen gas when heated even to melting. It contains, according to Proust, 9 per cent. of oxygen, and according to Thomson about 10 per cent. It yet remains to be proved whether it does not acquire some other ingredient from the long-continued calcination with coal-flame besides oxygen.

Massicot is the yellow oxyd formed by the calcination of lead in its progress to the state of minium, and probably resembles the yellow oxyd very closely, but is less uniform in its composition.

Minium or *red oxyd* is formed by long-continued calcination of lead, is insoluble *as such* in acids, apparently from being too highly oxygenated. Its composition is variously stated, and probably really varies according to the circumstances of manufacture. Vauquelin states it to contain generally no more than 9 per cent. of oxygen; Thomson, 12 per cent. and others somewhat higher.

Though it gives out oxygen when heated, and passes to the yellow oxyd, this is not an unexceptionable proof of its containing more oxygen, on account of the entire reduction of a portion which always takes place, but the strongest proof of its super-oxygenation is derived from the action of nitric acid as already described, and its separation into two oxyds, of which the *least oxygenated* is the yellow oxyd, but if it is really the basis of the sulphat of lead it would appear to contain no more than about 7 per cent.

The brown oxyd is formed by the further oxygenation of minium, is insoluble *as such* in acids, with muriatic acid gives oxymuriatic acid gas, gives out much oxygen on being heated, and contains, according to Thomson, 18.4 per cent. of oxygen, and according to Proust 21 per cent.

Litharge, according to Thomson, is the yellow oxyd combined with about 4 per cent. of carbonic acid.

The white carbonat is the yellow oxyd fully saturated with carbonic acid and water, both of which are driven off at a red heat and the yellow oxyd left pure.

All the pure oxyds or carbonated oxyds of lead are reducible with great ease when heated red hot in contact with carbonaceous matter. It is not necessary to mix them with any reducing flux, nothing more being required in the way of experiment than to lay them in a covered crucible lined with charcoal. The same reduction takes place when heated by the blow-pipe on charcoal.

When strongly heated per se, and especially

[l] Chenevix. Phil. Trans. for 1802. [m] Thomson.

in a draught of hot air, the oxyds of lead partly volatilize during vitrification.

§ 4. Lead is soluble in most acids. All the salts have a sweetish taste, and are strongly styptic or astringent in the mouth.

Prussiat of potash causes a white precipitate, and all the hydrosulphurets a deep black-brown precipitate, even in very minute quantities, so as to furnish an excellent test for the presence of this metal.

The sulphuric acid has no action on lead when cold, or even when moderately warmed, whether concentrated or dilute, but at a boiling heat the acid, when strong, dissolves this metal slowly with evolution of sulphureous acid, and a thick white pasty mass is produced which is the sulphat of lead. It is on account of the difficult solubility of lead in this acid that the chambers in which the sulphuric acid is made are lined with sheet lead, and the boilers in which it is first concentrated are of the same material, but a certain quantity of sulphat gradually collects, which is thrown away.

The salt procured in this way has always an excess of acid by which it is rendered slightly soluble in water, but after it has been washed with water the remainder is nearly neutral, and is scarcely soluble in more water. The first washings will crystallize by evaporation into small needles, which retain a small excess of acid. Sulphat of lead is also formed by adding sulphuric acid to any of the salts of the metal, such as the nitrat or muriat, but the decomposition is still more perfect when any of the alkaline or earthy sulphats is employed. In the former case some of the sulphat remains in solution till the liquor is quite evaporated by favour of the excess of acid, in the latter the whole is precipitated at once. Thus a large quantity of this sulphat is made in the preparation of the mordant of the bleachers by the decomposition of alum and acetited lead, acetited alumine being contained in the clear liquor, and a copious deposition of sulphat of lead falling down. Sulphat of lead is scarcely decomposable by mere heat, so that in all processes of analysis it may be dried freely at a moderate red heat without danger of error. On charcoal the metal is reduced. When very strongly heated *per se* it gives sulphureous acid gas.

The composition of this salt is given with but little variation by different chemists. The proportion of metal estimated by Kirwan is 71 per cent.[n] Klaproth (from the *artificial* sulphat which is the kind here described) gives in one case 70.37, and in another 71 per cent. as obtained by the actual reduction of 100 parts of the ignited sulphat; and Vauquelin makes it 70.4 per cent. All these eminent chemists also agree in fixing the quantity of oxygen united to these 70 or 71 of lead to be about 5 parts, which would form an oxyd in which the oxygen was no more than about 7 per cent. a proportion much less than that estimated to be contained in the yellow oxyd, which is supposed to be the basis of this salt. With regard to the quantity of sulphuric acid, 100 parts of the artificial sulphat of lead, when decomposed by acetited or nitrated barytes, give nearly 34 parts of sulphat of barytes, of which the real sulphuric acid is about 24, which therefore is the quantity contained in 100 parts of sulphat of lead.

On a general average therefore it may be stated that 100 parts of this salt heated moderately to redness consist of about 71 lead, 24 sulphuric acid, and 5 oxygen.

The action of the *sulphureous acid* on lead has been examined by Messrs. Fourcroy and Vauquelin.[o] This acid does not dissolve reguline lead, but the oxyds readily if not too highly oxygenated. When sulphureous acid is digested with minium the red colour is soon lost, and with it the pungent smell of the acid, and a white magma is produced, which is a mixture of sulphat and sulphite of lead. But if this acid be added to the nitrat of lead, only the sulphite of lead is produced, a collateral proof that in the nitrat the lead is less oxygenated than in minium.

This sulphite when well washed is insipid and insoluble. Heated with the blowpipe on charcoal, it first becomes yellow, and gives a faint phosphorescent flame, and then is entirely reduced. Heated gradually in a retort it gives out water, sulphureous acid, and sulphur, and at last a greenish-yellow sulphat of lead is left. Sulphuric and muriatic acid added to this sulphite make an effervescence and disengage sulphureous acid vapour, but the nitric acid changes it to the sulphat.

The *nitric acid* a little dilute dissolves lead with great steadiness, giving out an uniform moderate stream of nitrous gas. If the acid be in too small a quantity a white sub-nitrated oxyd is formed, but more of the acid brings it to a clear solution, except a small portion of a grey powder which Dr. Thomson finds to be oxyd of antimony with a little silex.[p] This solution is not made cloudy by adding pure water by which it may be immediately distin-

[n] Mineral Waters, Table 4. [o] Systeme de Conn. Chim. tom. 6. [p] Phil. Journ. vol. viii.

guished from the nitrat of bismuth. By due evaporation it readily furnishes large regular crystals, generally in the form of flattened trihedral pyramids with the apices truncated, but sometimes in truncated hexahedral pyramids. These crystals are of a pearl-white and soluble in about 7½ parts of boiling water. A hundred parts of nitrat of lead, dried at 300°, contain 61.⅔ of lead.[q] This salt when in solution is readily decomposed by sulphuric acid or any alkaline sulphat. Dry nitrat of lead, distilled *per se* in a full red heat, gives much nitrous gas, oxygen, and nitrous oxyd, and finally a yellow oxyd of lead remains which readily vitrifies and corrodes the sides of the earthen or glass vessel. But a portion is entirely reduced, so that globules of lead are found entangled in the vitrified oxyd. The loss sustained by nitrat of lead on being heated red-hot for half an hour amounts to about 40 per cent.[r]

Nitrat of lead, boiled with metallic lead, forms a salt much less soluble in water than the common nitrat, and appears under the form of yellow scaly crystals, as first noticed by Proust. These, Dr. Thomson has very satisfactorily shewn to be a *sub-nitrat*, as already described when mentioning the oxyds of lead and the sub-oxyd supposed by Proust to be formed in this way.

Nitric acid appears to be incapable of dissolving minium without first decomposing it, and causing it to separate into two portions one of them containing more and the other less oxygen than minium. Hence when these two substances are digested together, about six sevenths of the minium loses oxygen enough to dissolve and form the common nitrat, and the remaining seventh part passes to the state of the insoluble brown oxyd, as already mentioned when describing the oxyds.

The yellow oxyd of lead dissolves in nitric acid without effervescence of nitrous gas and the common nitrat is formed, and hence it is reasonably inferred that the metal of this salt is in the state of yellow oxyd, since the nitric acid is not decomposed in this case. The pure alkali likewise separates a yellow oxyd from the nitrat.

When *oxymuriatic* acid gas is passed through water with minium or any other oxyd of lead, it is readily absorbed, the oxyd becomes of a deep black-brown and a part is dissolved into a yellow liquor, the oxymuriat of lead, as first discovered by Proust. This salt is much more soluble than common muriat of lead. The same salt is formed by adding oxymuriatic acid to nitrat of lead, which does not produce an immediate white precipitate as the muriatic acid does, but gradually causes the deposition of the brown oxyd, which as already mentioned is lead in the highest state of oxygenation. An excess of the acid redissolves this oxyd.[s]

Potash or soda, added to this salt in solution, causes the precipitation of the brown oxyd, but ammonia immediately produces a white precipitate, which is probably muriat of lead formed by the disoxygenation of part of the oxymuriatic acid by means of the ammonia.

Muriatic acid dissolves lead when heated, but with difficulty. It combines readily with the yellow oxyd or the carbonated oxyd, expelling the carbonic acid of the latter.

But this muriat is more expeditiously formed by adding muriatic acid or any alkaline or earthy muriat to nitrat of lead, which causes immediately a white thick bulky precipitate, almost like a coagulum, and much more voluminous than that which is produced by adding the sulphuric acid. This salt is sweetish to the taste, and is soluble in about 22 parts of cold water, in which latter respect, as well as in not changing colour by short exposure to light, it may be distinguished from muriat of silver, which it resembles in outward appearance; and water may therefore be used to separate the muriat of lead from that of silver, but nitric acid is still preferable. The muriat of lead is also soluble in acetic acid, by which also it may be distinguished from muriat of silver, and from sulphat of lead. When the hot saturated solution of this salt cools gradually, much of it separates in small feathery crystals, and the rest in regular six-sided prisms.

Muriat of lead is not deliquescent. When heated by itself it readily melts, and a white vapour sublimes from the surface which leaves a very permanent sugary taste in the mouth. The melted salt has a semi-vitreous glossy appearance, and a grey-brown colour. It has been termed by the older chemists *plumbum corneum*, in analogy with the corresponding salt from silver the *luna cornea*.

The composition of this salt is given with some variation by different chemists. According to Klaproth, 100 grains dried fully, but short of volatilization, contain 75 of lead and 14 of muriatic acid (the latter being estimated by being combined with silver and taking the acid of luna cornea at 15.4 per cent.) and the remaining 11 parts are oxygen and water. According to Chenevix 100 parts of muriat of

[q] Ditto. [r] Ditto. [s] Fourcroy Systeme.

lead decomposed by nitrat of silver produce 81.3 of luna cornea, the acid of which is 12.5 parts. According to Kirwan 100 parts of muriat of lead fully desiccated contain 17 of muriatic acid and 83 of oxyd of lead, which last (if oxygenated at the rate of 9 per cent.) would indicate 75.5 of lead; if at 7 per cent. 77 of lead.

When muriatic acid is gently heated with minium the latter gives a part of its oxygen to the acid, part of which in consequence assumes the form of oxymuriatic acid, and the lead, now partially deoxygenated, unites with the remainder of the acid into the common white muriat of lead. This change takes place still more strikingly with the brown oxyd. But when minium is employed in a large quantity, no oxymuriatic acid is produced, but, instead of it, the brown oxyd and common muriat of lead.[a]

The *carbonic acid* unites readily with the oxyd of lead, forming (as already mentioned) the white carbonat when fully saturated, and in a less proportion, converting the yellow oxyd to the state of litharge. The proportions of these two carbonats have been already given. The white carbonat is produced by decomposing the nitrat or any other salt by a carbonated alkali. Water holding carbonic acid will readily dissolve enough of the oxyd of lead by remaining some time in contact, as to be very readily detected by the hydro-sulphurets.

Ceruse or *white lead* is a carbonat prepared in the first part of the process of making acetite of lead. It is made in the following way: lead is melted and cast in a case or mould, so as to form a sheet about two feet long, five inches broad, and from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch thick. The lead in this instance is cast at once of the proper form, and not mechanically flattened like sheet lead, that its texture may be more open, and more easily penetrated by the acid vapour. These plates are then rolled up into a loose coil, and each is laid perpendicularly in an earthen pot, like a common garden-pot, holding from two to six pints each, but with a ledge on the inside about half way down on which the coil of lead rests, so that it may not touch the bottom. Each pot is filled with vinegar of any kind, just so high as not to wet the bottom of the lead, and the whole is also covered with a plate of lead fitting very close. The pots are then ranged under a building, so as to shelter them from the weather, and buried pretty deep in fresh stable litter or Tanner's bark, layer upon layer, according to the number of pots. The heat of the dung soon fills the upper part of the pots, with the vapour of the vinegar below, and the lead kept constantly in contact with the acid vapour, but not immersed in the liquor, presently begins to corrode and oxidate at the surface. The pots remain under the litter for about two months, at the end of which time they are taken out and the coils of lead are found deeply corroded and the surface converted into a whitish scaly brittle oxyd. This is separated by passing the plates between rollers, which causes it to peel off, leaving the lead beneath in the metallic state. This oxyd is then mixed with a little water, and passed between a pair of mill-stones; then the finer parts are separated from the coarser by successive washings, the former being longer suspended in water than the latter, till the whole of the finer oxyd is obtained. This is then dried either in the air or in large airy rooms warmed by a small stove, and is then perfect ceruse or white lead fit for use. Of late years the scales of oxyd, instead of being separated from the coils by dry laminating, which raised a dust of lead highly injurious to the health of the people about them, are detached by spreading the coils upon a perforated wooden floor covered with water, and drawing them to and fro by rakes, which detaches the oxyd and causes it to sink through the water and the holes of the floor to the bottom of the vessel below.

The ceruse or white lead thus formed was found by Bergman to be a carbonated oxyd of lead, and not an acetite or sub-acetite, though the acetous acid is the means of its formation.

The *acetous acid* does not dissolve lead when in close vessels, but with access of air it first oxidates it, and then dissolves the oxyd. Or the solution may be made by adding oxyd of lead or carbonated oxyd to vinegar, and digesting for a time.

Acetite of lead, commonly called *sugar of lead*, is a salt used very largely in manufactures, particularly in calico-printing, and the preparation of it, though very simple, is confined to a very few places and countries. Most of the sugar of lead used in this country is imported from Holland. This salt is made very nearly in the manner of ceruse, that is, lead sheets are put into pots with vinegar and digested a sufficient time, but here the vinegar is distilled, and the plates, instead of being entirely out of the liquor, are half immersed in it.[b] This being done, the upper half is soon covered with

[a] Fourcroy.

[b] Pontier Journ des Mines, No. 69.

an efflorescence of ceruffe, after which it is immerfed in the vinegar, and the part which was before immerfed is now brought up to be converted into ceruffe as before, when the plate is again turned, and the newly oxydated furface in its turn buried in the liquor. The plates are thus turned about two or three times a day, and the vinegar in faturating itfelf with the ceruffe become milky, and foon fufficiently impregnated to be boiled down to the cryftallizing point, which is done in tinned veffels to about a third of the original quantity. This is then ftrained, and on cooling depofits the acetite in fmall long-needled irregular whitifh cryftals. The mother-liquor is again evaporated for a frefh crop of cryftals, but thefe are browner and fomewhat deliquefcent.

Acetite of lead may alfo be made directly by diffolving ceruffe or litharge in vinegar, and probably the natural carbonat will anfwer the fame purpofe. Some technical nicety appears to be required in making the falt cryftallize in the large way.

Sugar of lead has a remarkably fweet tafte, by no means unpleafant, but mixed with confiderable aftringency. By re-folution in boiling water and flow cooling, it changes its appearance confiderably, and affumes the form of large tranfparent tetrahedral prifms or lengthened parallepipeds. Carbonic acid in any form decompofes this falt, and caufes a white carbonat to be precipitated, and hence one caufe of the milkinefs which it ufually affumes with fpring water, but this is alfo partly owing to the fulphats contained in moft natural fprings.

When dry acetite of lead is brifkly heated without addition in a retort, it gives an acetous red fetid liquor, and the refidue of the diftillation furnifhes a good pyrophorus. But Prouft,[c] in diftilling it very flowly, obtained firft a watery vinegar, then a yellow liquid with the fmell of alcohol but rather empyreumatic, from which after a time ammonia was difengaged, and from which, when faturated with potafh, a ftrong fmelling etherial oil feparated. The liquid diftilled from the folution furnifhed a ftrong inflammable fluid refembling ether.

Litharge boiled with vinegar to entire faturation forms a reddifh-brown folution, univerfally known in medicine as Goulard's extract, and it feems to contain much more oxyd of lead than the common acetite.

The *tartareous acid* has no direct action on lead, but added to the red oxyd it whitens it, and if a few drops of the acid in folution be poured into the liquid nitrat, or any other foluble falt of lead, a white pulverulent tartrite of lead is feparated.

Tartar, or the fuper-tartrite of potafh, is partially decompofed by the falts or oxyds of lead; the excefs of tartareous acid uniting with the lead, and neutralized tartrite of potafh remaining in the folution.

The *oxalic acid* readily tarnifhes metallic lead, but diffolves the oxyds with much more eafe. The folution when faturated depofits fmall brilliant cryftals, which foon grow opake in the air.

Similar cryftals of oxalat of lead are alfo obtained by adding oxalic acid to nitrat or acetite of lead.

The *malic acid* unites readily with lead when added to any of its foluble falts. The malat of lead is again decompofed by the fulphuric acid, which is the method propofed by Scheele of obtaining this vegetable acid pure. (See *malic acid.*)

The *arfenic* acid added to lead firft blackens and then converts it to a grey powder. Scheele[d] found that when one part of lead fhavings was diftilled with two parts of dry arfenic acid the lead was diffolved, a little arfenic fublimed, and in the retort was left a milky glafs, which, boiled in water, left a white powder which was arfeniat of lead. Arfeniat of lead is alfo formed immediately by adding arfenic acid or any other arfeniat to the nitrat acetite or moft other falts of lead. The natural arfeniats of iron and copper are ufefully analyzed in this way. (See vol. i. page 102 and 352.)

Arfeniat of lead is however decompofed by fulphuric acid, and the arfenic acid left in the folution while the fulphat of lead fubfides. It is alfo foluble in acetic acid, which the fulphat of lead is not.

Many other of the acids unite with lead, forming falts little known, which will be found under thofe refpective acids.

The fixed alkalies diffolve the oxyd of lead, either by direct combination or by decompofing any of the acid falts of this metal by the alkali; and rediffolving the precipitated oxyd by an excefs of the alkali. None of the falts, however, can be completely decompofed in this way, for it is not ftrictly an oxyd that precipitates, but an infoluble falt compofed of the acid and an excefs of oxyd; as for example, when the muriat of lead is ufed, the precipitate is muriatic acid with an over proportion of oxyd (or a *fub-muriat*) and thereby rendered infoluble in

[c] Journ. de Phyf. vol. lvi. p. 208.

[d] Effays.

water alone, and the alkali only diſſolves this exceſs of oxyd. But the carbonated alkalies completely decompoſe the ſalts of lead.

The alkaline earths alſo diſſolve the oxyds of lead. The action of lime-water has been minutely examined by Berthollet.

Lime-water boiled for a long time on litharge forms a ſolution which has been long known as a recipe for blackening hair and other animal matters. When evaporated in a cloſe veſſel it depoſits ſmall tranſparent cryſtals of lime with oxyd of lead. This ſolution is decompoſed by the alkaline ſulphats and muriats, and alſo by ſulphuretted hydrogen.

Ammonia alſo diſſolves oxyd of lead but with difficulty, and it does not decompoſe the acid ſalts of this metal ſo readily as the fixed alkalies do.

Lead and nitre have but a very weak action on each other. When lead filings are projected on melted nitre, little if any deflagration is excited, but the metal is reduced to a yellow ſemi-vitrified foliated maſs reſembling litharge.

The action of the oxyds of lead on the alkaline muriats is attended with ſome ſtriking phenomena. In the numerous experiments for obtaining the alkali from muriat of ſoda, it was found that litharge was able completely to decompoſe this ſalt and produce a white maſs, whilſt the naked alkali remained in ſolution. This diſcovery has been applied to uſe in the large way on account of the fine yellow pigment which is obtained from the white maſs by calcination, and for which a patent was procured many years ago by Mr. Turner.

Vauquelin has elucidated this intereſting chemical phenomenon in his uſual maſterly manner.[e] He obſerves that we cannot admit this decompoſition to be the reſult of ſimple affinity without involving a direct contradiction, for if the oxyd of lead had a ſtronger affinity than ſoda for muriatic acid, muriat of lead could not be decompoſed by ſoda, which however is readily done to a certain extent. Nor can the carbonic acid of litharge be concerned in the explanation, ſince minium, which contains no carbonic acid, operates in decompoſing muriat of ſoda full as powerfully as litharge does.

But on the other hand muriat of ſoda is *completely* decompoſed by litharge, if the latter be in ſufficient quantity, ſo that this apparent contradiction cannot be explained by ſuppoſing the decompoſition only partial, but recourſe muſt be add to more complicated affinities.

The facts and experiments given by Vauquelin are the following: ſeven parts of litharge in fine powder were mixed with one of muriat of ſoda; the whole was moiſtened with water to the conſiſtence of thin ſoup and frequently ſtirred during ſeveral hours. By degrees the litharge loſt its natural colour, whitened, and ſwelled prodigiouſly, abſorbing all the water that was uſed at firſt, ſo that to prevent its hardening, it was neceſſary to add much more. As no further change took place after four days, the whole was examined. The liquid when filtered had a ſtrong alkaline taſte, and contained alſo a little muriat of lead but no muriat of ſoda. By evaporation it furniſhed cryſtals of carbonat of ſoda, rendered opake by a ſmall portion of muriat of lead. The ſubſtance from which the liquor had been ſeparated, when dried and waſhed, was of a dirty white, and weighed $\frac{1}{8}$ more than the litharge uſed. Heated gently it aſſumed a very fine lemon-yellow, loſing thereby about $\frac{1}{40}$ of its weight.

Part of this yellow ſubſtance digeſted with cauſtic ſoda changed to a dirty yellow, diminiſhed in ſubſtance, and the undiſſolved reſidue now changed from a powder to a cluſter of needled cryſtals. The alkaline liquor retained its natural taſte, but gave a copious black precipitate with hydroſulphuret of ſoda, ſhewing the preſence of much oxyd of lead. The needled cryſtals were common muriat of lead.

The white ſubſtance therefore left after the action of muriat of ſoda on litharge was muriat of lead with a great exceſs of oxyd (which laſt the ſoda diſſolved) or in other words a *ſub-muriat of lead*.

The ſame was alſo treated with weak nitric acid, which diſſolved all the exceſs of oxyd and left a white cryſtalline muriat of lead. The nitric ſolution gave by evaporation cryſtals of nitrat of lead mixed with ſome muriat.

Another portion of the ſame yellow ſubſtance was boiled with water but ſcarcely any was diſſolved, which inſolubility is therefore owing to the exceſs of oxyd, ſince common muriat of lead diſſolves in about 22 parts of hot water.

This ſub-muriat therefore has the following properties: it is inſoluble in water; cauſtic alkalies and nitric acid diſſolve only the exceſs of oxyd, and it is alſo owing to this exceſs that it aſſumes the yellow colour when heated.

Muriat of lead however cannot be entirely decompoſed by cauſtic ſoda, for when theſe two ſubſtances are digeſted together, ſufficient mu-

[e] Ann Chem. tom. xxxi.

riatic acid always remains combined with the oxyd of lead to bring it to the state in which it is found after the decomposition of common salt, that is, of the *sub-muriat*, which is proved by its becoming yellow when heated, and when treated with nitric acid, by yielding nitrat of lead, and common muriat of lead.

In the above experiments a singular complication of affinities operates.

According to Vauquelin, when the yellow sub-muriat of lead is treated with caustic soda, crystallized muriat of lead and a solution of soda are produced; so that this alkali has the power of abstracting the excess of oxyd from the sub-muriat: yet on the other hand, the crystallized muriat is decomposed by soda into the sub-muriat and muriat of soda; and an additional quantity of soda beyond what was necessary to saturate the muriatic acid, would again decompose the sub-muriat formed by the first portion, and by uniting with its excess of oxyd, would restore what remained undecomposed, to the state of crystallized muriat of lead.

Hence a large proportion of litharge is required to decompose common salt, for as caustic soda is actually produced in the process, it would in its turn react upon the sub-muriat of lead and deprive it of its excess of oxyd, unless this alkali had already met with sufficient oxyd of lead to saturate it. So that the affinities here acting, are those of muriatic acid for oxyd of lead, of muriat of lead for an excess of oxyd, and also of soda for oxyd, and there must therefore be sufficient oxyd to answer all these distinct affinities, and supply each of the substances mentioned with their separate portion.

According to Vauquelin also, there is a sub-nitrat and a sub-sulphat of lead, made also by adding to the common sulphat and muriat a small quantity of caustic alkali, particularly ammonia, by which the sub-sulphat or sub-nitrat is precipitated.

Turner's Patent Yellow, or the sub-muriat of lead made yellow by heating, is thus made according to the specification of the patent:[f] take any quantity of minium, litharge, or calx of lead, add half the weight of common salt, with water sufficient to dissolve it, mix them by long trituration, and let them stand together at least for twenty-four hours, by which time the lead will be changed into a good white, then wash out the alkali and calcine the lead till it becomes yellow; which will be of different tints according to the continuance of calcination and degrees of heat. As only twice as much litharge as salt is here employed, it is probable that some of the salt remains undecomposed.

The oxyds of lead readily decompose muriat of ammonia. If this salt and minium are rubbed together even without heat, a strong smell of ammonia rises, and by distillation properly conducted, caustic ammonia may be prepared in this way as well as by muriated ammonia and lime. If litharge be used, some carbonat of ammonia is also obtained, and with the white carbonat of lead the entire ammoniacal product is carbonated. The residue in each case is muriat of lead, in the form of a grey brilliant brittle mass.

Borax readily unites with all the oxyds of lead by fusion into a fine soft yellow glass.

Lead unites with *Sulphur* with great ease. This may be effected either by adding sulphur to melted lead, or by heating alternate layers of sulphur and lead clippings in a crucible. The proportions are of little importance, two or three parts of lead to one of sulphur are generally used. The result is a black scaly powder. When the mixture is heated to a certain point it takes fire, and the excess of sulphur flies off. Sulphuret of lead is fusible, but requires a red heat, being less easily melted than either of its constituent parts.

When slowly cooled after fusion, it forms a black, harsh, brittle mass, readily crystallizing in cubic facets, particularly if the fluid part of the mass is poured off when the sides have fixed by cooling. This artificial sulphuret much resembles the natural galena in appearance.

Sulphuretted alkali acts with extreme energy on lead, dissolving it readily by fusion.

All the *Hydrosulphurets* either with or without an alkaline or earthy basis immediately unite with lead in any liquid combination, whether dissolved by acids or alkalies, or alkaline earths, and produce a very dark brown hydrosulphuret which being insoluble slowly falls to the bottom of the liquor. In this way very minute portions of lead are readily detected in wines and other liquids that may be suspected to contain this dangerous metal. Sulphuret of potash or of lime dissolved in water forms a hydrosulphuret very proper for this purpose, or sulphuretted hydrogen gas simply dissolved in water will answer as well. But as the salts of iron and some other metals are equally blackened by this test, some method of distinction is adviseable when liquors are to be examined with regard to their supposed noxious qualities. This is partly effected by adding a weak acid, such as the tar-

[f] Repertory, vol. xii.

tareous to the sulphuretted test, which will re-dissolve the hydro-sulphuret of iron, but not that of lead. (See *Wine.*)

Phosphorus easily unites with lead according to Pelletier's experiments,[g] by melting in a covered crucible a mixture of one ounce of vitreous phosphoric acid, one dram of charcoal, and one ounce of lead clippings.

The phosphuret is considerably malleable, and little different from common lead in appearance, but when heated the phosphorus burns off. It readily tarnishes in the air. It is also made by projecting phosphorus on melted lead.

The fat oils dissolve the oxyds of lead with great ease, and undergo a remarkable change in the process, being thereby rendered *drying*, or capable of speedily hardening into a firm varnish when exposed to the air. Some oils, particularly olive oil, acquire at once a very firm consistence and a considerable adhesive property, when gently warmed. It is in this state the common white *diachylon plaster*. See the articles OIL and PLASTER.

Lead is capable of uniting with many other metals, forming alloys, some of which are of use in the arts.

With antimony lead forms an alloy which is brittle, when the latter exceeds about $\frac{1}{4}$. In addition to what is mentioned under the article *Antimony*, some experiments of Prof. Gmelin may be noticed.[h] The lead was first melted separately, and when fused a little suet was thrown on the surface; after which the antimony was thrown in, in powder, the whole well stirred, and poured out without loss of time into an iron mould. Equal parts of the two metals produced a close alloy of lamellar texture, of considerable lustre in the fracture, and very brittle. Sp. gr. 7.22. Two parts of lead and one of antimony gave a less brilliant alloy, of a granular texture, yielding a little to the hammer. Sp. gr. 11. Three of lead and one of antimony gave an alloy of a duller colour, granular, and extending moderately under the hammer.

Four of lead and one of antimony forms, according to Rinman and other authors, the common type-metal of the letter-founders, though some add a little copper or brass. This resembled the last-mentioned alloy in appearance, and would not take a polish. Sp. gr. 9.571.

Eight parts of lead and one of antimony gave an alloy very like pure lead, but harder and more sonorous, and of a close granular texture like steel. Sp. gr. 11. Twelve of lead and one of antimony gave an alloy scarcely less malleable than lead, and capable of extending into very thin leaves.

Antimony therefore is found to harden lead very considerably, and hence its use in type-metal, and also probably in bullets, where greater hardness is required, but it does not add materially to its lustre, except in a quantity which totally destroys the malleability.

Lead and bismuth unite with great ease, and form alloys of remarkable fusibility, particularly with a small addition of tin, as described under the article *Bismuth*.

Lead and cobalt unite but with difficulty, forming an unimportant alloy. (See COBALT.)

Lead alloyed with copper forms *pot-metal*. (See COPPER.)

For the important alloy of lead and tin, see TIN.

Lead and zinc do not unite readily unless by particular management. Beaumé found that when simply melted together, and cooled slowly the lead fell to the bottom of the crucible, and the zinc remained at the top unmixed. Besides, if they are kept together in fusion and repeatedly stirred, the zinc sublimes off with great rapidity. But Gmelin[i] succeeded completely in alloying these metals by first melting the lead, covering it with suet, then throwing in the zinc, and as soon as the latter appeared to be uniformly mixed (probably by help of stirring) and the blue zinc-flame began to appear, removing the crucible, and suddenly cooling the mixture by pouring it into an iron spoon. Some of the results of these experiments we shall mention: Equal parts of lead and zinc gave a metal of a lamellated texture, so ductile as to bear hammering into a pretty thin blade, harder than lead, and very bright when just filed. Sp. gr. 7.66.

Three of lead and one of zinc gave an alloy more leaden in appearance, but harder, more sonorous, and brighter. Four of lead and one of zinc gave an alloy still more leaden, but yet sensibly harder and capable of a good polish. Twelve parts of lead and one of zinc still retained a much greater degree of hardness, sonorousness, and lustre on the polished surface, than pure lead. Sixteen parts of lead and one of zinc scarcely differed from lead in appearance, but the specific gravity was less, being only 10.617.

The affinities of the oxyd of lead to the different acids are in the following order.[k] The

[g] Memoires, tom. i. & ii. [h] Comm. Soc. Gotting. tom. x. [i] Comm. Gott. ibid. [k] Thomson.

fulphuric, faccholactic, oxalic, arfenic, tartaric, muriatic, phofphoric, fulphureous, febacic, nitric, fluoric, citric, lactic, acetic, boracic, pruffic, and carbonic acids.

LEAD (White) or *Ceruffe*. (See the foregoing article.)

LEAD (Sugar of) or *Acetite of Lead*. (See the foregoing article.)

LEATHER.

The preparation of the fkins of animals for the many important purpofes to which they are applied is almoft exclufively a chemical procefs in all its branches, and as fuch will deferve a general notice in this place.

The art of preparing leather is unqueftionably one of the moft ancient known, and is practifed in every country on the face of the globe with a general fimilarity of method, the refult of obvious reafoning, and long experience.

The objects fulfilled in converting fkin into leather are to prevent the deftruction by putrefaction, which unprepared fkin would undergo (though flower than with moft other parts of animals) and to render it ftrong, tough, and durable, and in fome inftances impervious to moifture.

The recent fkin ftripped off an animal confifts principally of the true cutis, or membranous texture, the chemical compofition of which is gelatin in a denfe ftate, but ftill entirely foluble in water more or lefs eafily, according to its denfity. This however is penetrated with different veffels for blood, lymph, oil, &c. fome of the contents of which muft of neceffity remain after the death of the animal, and is covered on the outfide with the infenfible cuticle to which is attached the exterior covering of hair, wool, fur, and the like. The chemical compofition of the cuticle and its investing hairy covering, appears to be condenfed albumen, infoluble in water, and nearly incapable of itfelf of putrefaction, but readily feparable from the true fkin by flight mechanical violence after the adhefion has been weakened by incipient fermentation or putrefaction, or the chemical action of lime, alkalies, or acids.

The preliminary fteps of all the proceffes for making leather confift in feparating from the cutis adhering impurities and foreign matters, the animal juices retained in its pores, and the cuticle with its hairy covering, (except on the very few cafes in which the latter is purpofely left on.) The true fkin being thus obtained nearly pure, and its texture fo far opened as readily to imbibe any fubftance in which it is macerated, is then converted into leather in different methods, of which there are two quite diftinct from each other: namely, that of *tanning*, or impregnating it with that peculiar vegetable matter called tan, and *tawing*, in which it imbibes alum and other falts, and afterwards fome foluble animal matter, fuch as the white of egg, or fometimes blood. Thefe two proceffes are alfo fometimes combined, that is, firft by tawing, and afterwards finifhing with a flight tanning. A large portion of the tanned leather alfo undergoes the further operation of *currying*, or imbuing with oil of fome kind with much manual labour, in order to render it fupple, flexible, and ftill more impenetrable by water. As familiar examples of each, the thick fole-leather of fhoes is *tanned*; the white kid leather, as it is called, for fine gloves, is *tawed*; the upper leather for boots and fhoes is *tanned* and *curried*; and the fine Turkey leather is *tawed*, and afterwards finifhed with a flight *tanning*.

The flight variations in the preparation of different kinds of leather are fo numerous, that only fome of the leading proceffes can be here defcribed.

Tanned leather. All fkins undergo a confiderable preparation before they are fit to receive the tanning lixivium. In moft parts of England the procefs is the following for the thin fkins of cows, calves, and thofe that are ufed for the more flexible kinds of leather, moft of which is afterwards finifhed by currying. The hide is firft thrown into a pit with water alone to free them from loofe dirt, blood, and other impurities. After lying there for a day or two it is placed upon a folid half-cylinder of ftone, called a *beam*, where it is cleared of any adhering fat or flefh. It is then thrown into a pit containing lime and water, in which it is kept for feveral days with frequent ftirring. The ufe of this is to loofen the hair and cuticle, after which the hide is again ftretched on the beam and the hair entirely fcraped off with a blunt knife made for the purpofe. The hide being well freed from the lime is then put into a pit called the *maftering*-pit, which is a bath compofed of water and the dung of fome animal, generally hens or pigeons, or dogs, or, where it can be had, of fea-fowl, diffufed through the water. The dung of horfes or cows will not anfwer, not being fufficiently putrefcent. Here the hide remains for fome days, more or lefs, according to its texture,

and from being hard and thick (the effect of the lime-water) it becomes very soft and supple. Where the hide is very thin and fine, extreme care is requisite in regulating this part of the process, for the putrescent dung is found so powerful an agent, that if the skin is kept in it only a few hours too long its texture is irrecoverably destroyed, and it is reduced to a gelatinous mass, which pulls to pieces with the slightest force. The hide is then thoroughly cleaned on the beam, and is fit for tanning.

The large thick ox or boar's hides intended for the toughest sole-leather, or where a very strong leather is required, are prepared in a different way. Being first cleaned in water, they are sometimes rolled up in heaps and put into a warm place where they speedily begin to putrify. The hair is then loosened, and may be scraped off sometimes with, and at other times without, the process of liming. The reason why the liming is generally omitted is that the lime, if retained in the skin, renders it too hard and liable to crack, and it is not so easy to wash it out from these as from the thinner hides. But on account of the thickness of the hide and the closeness of its texture it is not fitted to receive the tan liquor till its pores are more completely opened, and this is usually done by immersing it for several days in a vat containing a sour liquor, an impure acetous acid, formed from rye or barley flour strongly fermented. The acid generated in the process seems to be a principal agent in opening the texture of the skin, but this is doubtless assisted by the continuance of the fermentation, of which the skin itself partakes. This process is called *raising*, and, it always immediately precedes that of tanning. Here also much care is required not to weaken the texture of the skin too much, for if kept too long in this process it would be corroded and spoiled. The hide comes out of this bath considerably swelled and softened.

Instead of this part of the process, which is often difficult to manage properly on account of the effect of the weather and other external causes on the necessary fermentation, Dr. Macbride has proposed the use of sulphuric acid extremely diluted, and this appears now to be pretty generally adopted. The proportions employed are about a wine pint of oil of vitriol to fifty gallons of water. Though the vitriolic bath is found to have as good an effect as the rye and barley sourings in preparing the hides for the tan, the action of the two substances seems to be considerably different. In the latter the acetous acid is doubtless the chief agent, but the fermentation still continues as is proved by the readiness with which the skins are rotted if this is too high or too long continued. The skin also after raising in this way is thickened and softened. But the vitriolic bath is incompatible with any fermentation, and most powerfully checks this process, and hence the skin is not readily spoiled by very long immersion, and it comes out thickened and hardened. It should seem however that each method answers perfectly well.

The next process is that of *tanning*, which is essentially the same for all skins, however previously prepared, and is founded on the following chemical facts. A great variety of vegetable substances, that is all those that give an astringent taste when chewed (such as the bark of oak, willow, alder, and many other trees, the gall-nut, tea-leaves, &c. &c.) when macerated in water, hot or cold, yield to this menstruum a substance eminently astringent, of a greyish-white when pure, which is called *tannin* or *tan*, whose properties will be more fully described under that article. When any kind of skin is soaked in an infusion of tan it gradually absorbs it or extracts it from the water in which the tan is dissolved, and the skin thereby becomes of a firmer texture, sensibly heavier, no longer capable of putrefaction or any spontaneous change, less easily pervious to water, and no longer soluble in this fluid even at a boiling heat, which all untanned skin is, whatever be its previous preparation. The art of tanning therefore essentially consists in nothing more than immersing skin for a sufficient length of time in an infusion of tan from vegetable bark or other sources till it is completely saturated with this principle. Hence the art of preserving the hides of animals by this method is one of the most antient and universal of all manufactures, no apparatus whatever being required to perform it, except a pit or hole of water in which the tanning vegetable may be put, and the skin thrown in along with it. And even in the most careful and improved methods of tanning, almost equal simplicity is observed in the operation, except that some art is used in regulating the strength of the tan-infusion, and some little manipulation in stirring the hides to give every part an opportunity of being thoroughly and equally soaked.

The substance used for tanning in this country is almost invariably oak-bark. The timber

being felled in ſpring (when the ſap has riſen) the bark is ſtripped off and piled in large ſtacks, protected from the wet by a ſhed, but open at the ſides to admit a free circulation of air through it. The bark before uſing is ground into coarſe powder, and is thrown into pits with water, by which an infuſion of the tan and other ſoluble parts is made, which is called technically *ooze*. The hides previouſly prepared in one or other of the ways above mentioned are then put firſt into ſmall pits with a very weak ooze, where they are allowed to macerate for ſome weeks with frequent ſtirring or *handling* as it is called. The ſtrength of the different oozes is increaſed gradually, after which the half-tanned hides (if of the thick kind intended for ſole-leather, and which require very complete tanning) are put into larger pits with alternate layers of ground bark, in ſubſtance, till the pit is filled, over which a heading of bark is alſo laid, and the interſtices filled up with a weak ooze to the brim. The hides thus are expoſed to the full action of an ooze nearly ſaturated with tan, and ſupplied with more of this principle from the bark in ſubſtance, in proportion as the ſkin abſorbs that portion already diſſolved, till the tanning is judged to be complete. This for the heavieſt kind of leather requires never leſs than fifteen months. Skin is known to be fully tanned by cutting a ſmall piece off the edge of the hide, and obſerving the change of colour. As far as the tan has fully penetrated, the colour is of a nutmeg-brown, but the reſt is white; and therefore before the proceſs is complete the upper and under ſides are brown, and a white line or ſtreak is ſeen in the middle.

Laſtly, when fully tanned the hide is taken out to drain, and ſtretched upon a convex piece of wood called a *horſe*, on which it is thoroughly ſmoothed, and beaten with a heavy ſteel pin, or ſometimes paſſed between iron cylinders, to make it more ſolid, and at the ſame time ſupple, after which it is taken to the *drying-houſe*, a covered building with apertures for the free admiſſion of air, where it remains till perfectly dry.

The common calves-ſkins require for the whole proceſs of converſion into leather in this way from two to four months, the thick ſole-leather hides from fifteen to eighteen or twenty months, and a boar's ſhield can hardly be finiſhed in leſs than two years. Leather gains in weight and improves in quality the longer it is ſuffered to remain in the ooze (within certain limits), and, as it is ſold by weight, this is alſo ſometimes an object to the tanners, though counterbalanced to a great degree by the length of time that muſt elapſe before his capital is returned.

The art is indebted to M. Seguin, a tanner of extenſive buſineſs in France, for the firſt accurate explanation of the rationale of the proceſs of tanning. According to the ancient idea of this proceſs the effect of the infuſion of aſtringent vegetables was ſuppoſed to be little elſe than mechanical, and that it acted in *conſtringing* or *condenſing* the fibres of the dead ſkin, as it corrugates the ſkin of the palate when taſted, and hence rendered it nearly impervious to moiſture and unſuſceptible of putrefaction. This explanation however did not accord with the actual increaſe of weight which the ſkin acquires by tanning, and which amounts on an average to an increaſe of from one-third to one-fourth of the weight of the ſkin when dry. M. Seguin, reaſoning from the circumſtance that ſkin before tanning is completely reſolved by water into a liquid jelly, but is inſoluble after tanning, was led to the ſimple experiment of adding a ſolution of ſkin (or glue) to an infuſion of oak-bark, and found an immediate precipitate of a thick tough extenſible dun-white matter, ſtrongly ſmelling of tan, and inſoluble in water at any heat, and which when dry becomes of a dark-brown colour and brittle.

This precipitate is an intimate combination of gelatin with that part of the vegetable infuſion which gives the tanning property, and being altogether a peculiar ſubſtance is denominated *tannin* or *tan*, whoſe properties will be more fully deſcribed under that article. This precipitate therefore hardly differs from tanned leather in any thing but in wanting the fibrous organized texture, and what other principles the ſkin may have abſorbed from the bark-infuſion during the maceration of ſeveral months, which a ſudden precipitation would not effect. Tanning therefore conſiſts chiefly in a ſlow and moſt intimate combination of vegetable *tan*, with the fibre of the ſkin, which continues till the latter is ſaturated through its whole thickneſs.

But oak-bark contains other ſoluble matter, which certainly alſo enters the texture of the ſkin along with the tan, and moſt intimately combines with it, for ſkin, when it has undergone the previous preparation already mentioned, appears to be able to abſorb, and when

absorbed to retain a great variety of vegetable and animal substances. The infusion of oak-bark contains, besides tan, the gallic acid and an extractive matter, all of which contribute to the process, and form a part of the tanned leather. That the gallic acid is absorbed is proved by the instant blackness which the leather assumes when merely rubbed with a solution of any salt of iron. The extract appears to be that which gives the leather its colour, and some degree of flexibility, and from the excellent observations of Mr. Davy on the process of tanning*, it seems probable that the quantity of tan absorbed is a good deal regulated by the quantity of extract present, being in general (the time of immersion and strength of the tan-infusion being nearly equal) in *inverse* proportion to the quantity of extract or of mucilage present in the infusion. This is found by comparing the actual weight acquired by leather, by quick tanning in infusions of different tanning materials, the composition of which has been previously ascertained by chemical analysis. The difficulty in experiments of this kind of obtaining tolerable accuracy is however very great, much greater than in the analysis of metals or minerals, on account of the great want of characteristic marks of distinction between vegetable matters, when a little changed by chemical union with other bodies, and the readiness with which their characters are irrevocably lost by the common action of re-agents.

The strength of the tanning infusion also most materially affects the quality of the leather and the weight which the skin gains during the process. As tan is more soluble than extract, a solution made hastily, and with a large portion of the material, will be nearly saturated with tan, and contain comparatively but little extract; and on the other hand the residue of the above infusion, macerated for a longer time in fresh water, will give a solution in which there is but little tan, but a large quantity of extract. Now it would seem that skin has the power of fixing a larger quantity of tan than of any other material, particularly than of extract, so that if already nearly saturated with extract, it will of course absorb much less tan than before, and therefore the entire increase of weight will be much less in this way than with tan alone. The quality also of the leather will of course be probably different when compounded of skin and tan with very little other ingredients than when it is a compound of skin and tan with a larger portion of extract; and in particular the former seems to be more brittle and less urable than the latter, as far as experiments have hitherto been made. The mere duration of the process also, as regulated solely by the strength of the infusion, that is where precisely the same infusion is used, but more or less diluted, may probably considerably affect the quality of the leather, for when the process goes on very rapidly it is possible that the outer part of the skin may be tanned strongly before the inner part is penetrated with the liquor, and as tanning gives a closeness of texture and difficult permeability to liquids it may happen that this very circumstance may prevent that uniformity of saturation with tan which would seem desirable.

The precipitate made by a solution of gelatin dropped into an infusion of any tanning vegetable matter appeared by Mr. Davy's experiments to be tolerably uniform in its composition whatever be the other constituents of the vegetable infusion. Thus when galls were used the precipitate contained about 46 of tan and 54 of gelatin, with catechu it contained 41 per cent. of tan, with oak bark 41 per cent. and with the Leicester willow 43. But real skin will never acquire such an increase of weight as the solution of gelatin either because other substances enter the composition of leather, or because the texture of the skin will not allow it to condense and chemically unite with so much tan as the same skin when dissolved in the form of glue, for glue (as mentioned under the article *Gelatin*) is only a solution of the refuse part of skin. Thus it was found that a piece of skin compleatly tanned by three week's immersion in a strong infusion of galls only gained weight in the proportion of 39 to 61 of skin; and this was even the greatest increase of weight observed, (being much more than that of common leather,) and in consequence made a much harder and more brittle leather.

With regard to the effect produced by the time of immersion, it was found in different experiments that skin apparently equally well tanned in each case, absorbed much more tan by rapid than by slow tanning: 100 parts of leather prepared in 2 weeks, containing 73 of skin and 27 of tan and other materials absorbed from the oak bark infusion, and the same quantity of leather prepared in 12 weeks (the infusion being proportionably weaker) containing 85 of skin and 15 of tan and other vegetable matter. A similar difference was found when infusion of willow bark was employed.

* Jour. Royal Instit. and Phil. Trans. for 1803.

The supposed improvement in the process of tanning practised and actually proposed by M. Seguin may here be shortly mentioned. This ingenious artist wishing to abridge the enormous time employed in common tanning (and consequent expence) and considering the tan as nearly the only active principle in this process, adopted the plan of using solutions of tan, instead of the mixture of bark and ooze usually employed, and of several and known degrees of strength in which the skin might be rapidly passed from the weakest to the strongest by a more regulated gradation than is usually done. For this purpose he had a series of vats containing the oak-bark, and began by pouring water on one of them, and after a short time drawing it off clear through a hole at the bottom. This first ooze was then poured on the bark of the second vat, and drawn off as before, by which it became sensibly stronger of tan. This liquor again was used to the third vat, and again to a fourth, according to the number, till it became quite saturated with tan. In the mean time fresh water was poured on the bark of the different vats in the same order, which produced a second ooze still very strong but inferior to the first: and thus three or four or more different oozes were obtained, all differing in strength, and which was the tanning liquor employed. The skins then being previously prepared in the way already described, were passed successively through the different oozes, beginning with the weakest and ascending to the strongest till they were compleatly tanned, which was known by the disappearance of the white line in the middle of the skin when cut through.

It appears beyond a doubt that the process of tanning is most materially shortened by this method of M. Seguin, and that very perfect leather is produced, but though now known for several years it does not appear to be adopted to any extent in this country, where leather is manufactured in vast quantities both for home consumption and for exportation to many parts of Europe, in which English leather is in the highest repute. From the way in which the oozes are made, according to M. Seguin, they must of necessity contain much more tan in proportion to the extract and other vegetable matter than where the bark itself is suffered to remain in substance along with the ooze and skin for many months, as the tan is much the most soluble of all the substances that are to be extracted by water, so that bark may readily be exhausted of tan, long before the extract, resin, gallic acid, and other materials are got out. It is said that the leather prepared in this new method is less durable and more brittle than in the old way.

The only real improvement of late adopted in this part of the process is to use some of the oozes warm by which the skin is sooner penetrated with the ooze, and a saving of time made of some consequence.

Dr. Macbride proposes lime-water to be used instead of common water for the extraction of the tan from the oak-bark, but this seems to be mischievous, as the only assignable effect of the lime would be to contract a firm union with a portion of the gallic acid and the tan, the result of which would be an insoluble calcareous substance utterly unfit for any purposes of tanning.

Of Tawing, Leather-dressing and dyeing, and other processes.

The dressing and preparing of the skins of lambs, sheep, goats, and other thin hides, though in many particulars closely resembling the method used with the thick cow and ox hides, forms usually a totally distinct branch of business, and is one in which a good deal of practical skill and nicety of manipulation is required to succeed perfectly. The processes are very various according to the article required, and this branch of the manufacture supplies the immense demand of white and dyed leather for gloves, the (so called) morocco leather of different colours and qualities for coach linings, book-binding, pocket-books, and thin leather for an infinite number of smaller purposes. Of these the white leather alone is not tanned but finished by the process of tawing, but the coloured leather receives always a tanning (generally by sumach) independent of the other dyeing materials. The previous preparation of each, or that in which the skin is thoroughly cleansed and reduced to the state of simple membrane in which it is called *pelt*, is essentially the same whether for tawing or dyeing. It is thus performed at the best manufactories at Bermondsey, near London, a place long celebrated for all branches of the leather business.

By far the greater number of the skins are imported: if lambs they are thus prepared; the skins are first soaked for a time in water, to cleanse them from any loose dirt and blood, and put upon the beam commonly used for the purpose, which is a half cylinder of wood covered with strong leather, and scraped on the flesh side with the semicircular blunt knife with two handles used in this operation. They are then hung up in considerable numbers in a small close room heated by flues, where they remain to

putrefy for a given time, as is easily perceived by the strong ammoniacal odour which issues from them when the door is opened. During this process a thick filthy slime works up to the surface of the skin, by which the regularity of the process is judged of; and the wool is loosened so that it readily comes off with a slight pull. Each skin is then returned to the beam, the wool taken off and preserved, and all the slime worked off with the knife, and the rough edges pared away. The skin is then put into a pit filled with lime water and kept there from two to six weeks more or less according to the nature of the skin, which has the effect of checking the further putrefaction, and produces a very remarkable hardening and thickening of its substance, and probably also it detaches a further portion of the slime. The skin is again well worked upon the beam, and much of its substance pared down, and all inequalities smoothed with the knife. Much pains and judgment are required in these operations on the one hand not to endanger the substance of the skin by the putrefaction (which if carried on too long would soon reduce it to an incohesive pulp) and on the other hand to work out every particle of the slime, the least of which if retained will prevent the skin from dressing well in the subsequent processes, and from taking the dye uniformly and well. The skin is then again softened and freed from the lime by being thrown into a vat of bran and water, and kept there for some weeks in a state of gentle fermentation, being occasionally returned to the beam. All the thickening produced by the lime is thus removed, and the skin is now as highly purified as possible, and is a thin extensible white membrane called in this state a *pelt*, and is now fit for any subsequent operation of tawing or dyeing, or oil dressing, or shammoying.

The method of bringing kid and goat's skins to the state of pelt is nearly the same as for lambs, except that the liming is used before the hair is taken off, the hair being of no great importance, and only sold to the plaisterers, but the lamb's wool, which is more valuable, would be injured by the lime. Kids' skins will take a longer time in tanning than lambs'.

If the pelts are to be *tawed* they are then put into a solution of alum and salt in warm water, in the proportion of about three pounds of alum and four pounds of salt to every 120 middle-sized skins, and worked about therein till they have absorbed a sufficient quantity. This again gives the skin a remarkable degree of thickness and toughness.

The skins are then taken out and washed in water, and then again put into a vat of bran and water and allowed to ferment for a time, till much of the alum and salt is got out and the unusual thickening produced by it is for the most part reduced. They are then taken to a lofty room with a stove in the middle, and stretched on hooks and kept there till fully dry. The skins are then converted into a tough, flexible, and quite white leather, but to give them a glossy finish, and to take off the harshness of feel still remaining, they are again soaked in water to extract more of the salt, and put into a large pail containing the yolks of eggs beat up with water. Here the skins are trodden for a long time, by which they so completely imbibe the substance of the egg that the liquor above them is rendered almost perfectly limpid, after which they are hung up in a loft to dry and finished by glossing with a warm iron. There are other smaller manipulations, which need not be here mentioned.

The essential difference therefore between *tanning* and *tawing* is, that in the former case the pelt is combined with tan and other vegetable matter, and in the latter with something that it imbibes from the alum and salt (possibly alumine) and which certainly is never again extracted by the subsequent washing and branning.

The (so called) Morocco leather, prepared from sheep-skins chiefly, and used so largely for coach-linings, pocket-books, and the best kind of book-binding, is thus made. The skin, cleansed and worked in the way already described, is taken from the lime-water, and the thickening thereby occasioned is brought down, not by bran liquor as in tawing, but by a bath of dogs' or pigeons' dung diffused in water, where it remains till sufficiently suppled, and till the lime is quite got out and it becomes a perfectly white clean pelt. If intended to be dyed red it is then sewed up very tight in the form of a sack with the grain side outwards (the dye only being required on this side) and is immersed in a cochineal bath of a warmth just equal to what the hand can support, and is worked about for a sufficient time till it is uniformly dyed, a process that demands much skill and experience. The sack is then put into a large vat containing sumach infused in warm water, and kept for some hours till it is sufficiently tanned.

The skins intended to be blacked are merely sumached without any previous dyeing. After some further preparation the colour of the fine red skins being finished with a weak bath of

saffron, the skins when dry are grained and polished in the following way. They are stretched very tight upon a smooth inclined board, and rubbed over with a little oil to supple them. Those intended for black leather are previously rubbed over with an iron liquor, by means of a stiff brush, which, uniting with the gallic acid of the sumach, instantly strikes a deep and uniform black. They are then rubbed by hand with a ball of glass cut into a polygonal surface, with much manual labour, which polishes them and makes them very firm and compact. Lastly, the *graining* or ribbed surface by which this kind of leather is distinguished is given by rubbing the leather very strongly with a ball of box-wood, round the centre of which a number of small equidistant parallel grooves are cut in, forming an equal number of narrow ridges, the friction of which gives the leather the desired inequality of surface.

The common mode of *currying* leather for shoes, boots, &c. consists in first softening the hides as they come from the tan-pit, partly by soaking in water, partly by mechanical means, and then impregnating it with some kind of oil, by which means it is rendered much more impervious by moisture, and proper to protect the feet from the inclemency of the seasons. The process in a few words is the following: the hide is first soaked thoroughly in water, then placed on a polished wooden beam with the flesh side outwards, and pared with a broad sharp knife till all the inequalities are removed and it is reduced to the required thinness. It is then again washed and rubbed with a polished stone, and while still wet it is besmeared with curriers oil, generally fish-oil, or a mixture of this and tallow. When hung up to dry the moisture evaporates, and the oil, which cannot be dissipated by mere exposure, gradually takes the place of the moisture, and penetrates deeply into the pores of the leather. It is then dried either in the sun or in a stoved room.

Blackening the leather is also a part of the curriers business, which is done on the grain side, simply by rubbing with an iron liquor, but on the flesh side with a mixture of lamp-black and oil.

Shammoyed leather is generally sheep or does skin, prepared in the way already mentioned by dressing, liming, &c. and dyed if necessary, and then finished in oil. This forms the common wash-leather, breeches leather, &c. and is the only kind which, when dyed, will bear washing without the colour being materially injured.

Common boot-leather, as usually prepared, is still in some degree pervious to water by long exposure to wet, and therefore fishermen, wild-fowl shooters, and those whose employment or amusement leads them to be long on wet ground, usually prepare their boots with an additional dressing of some oily or resinous matter.

The punt-shooters in Cambridgeshire and the adjoining fenny parts of England, use the following mixture with very good effect.[b] Melt together in an earthen pipkin ½ lb. of tallow, 4 oz. of hog's lard, 2 oz. of turpentine, and as much bees-wax: make the boots thoroughly dry and warm, and rub in this mixture well with a little tow as hot as the hand can bear, or else hold the boots over a very gentle fire till the leather has thoroughly imbibed it. Another mixture for the same purpose, and used by fishermen, is: bees-wax, Burgundy pitch, and turpentine, of each 2 oz; tallow, 4 oz.: or ½ lb. of bees-wax, ¼ lb. of rosin, and ¼ lb. of beef-suet. In all cases the boots must be quite dry, and the mixture applied very warm.

It only remains on the subject of leather to notice very shortly some of the most remarkable kinds of leather prepared in foreign countries, for the general methods of making leather resemble each other very closely in every part of the globe.

The process for the real Morocco leather, as prepared from goat-skins at Fez and Tetuan, is thus described by M. Broussonet.[c] The skins are first cleansed, the hair taken off, limed and reduced with bran nearly in the way already described for the English Morocco leather. After coming from the bran they are thrown into a second bath made of white figs, mixed with water, which is thereby rendered slimy and fermentable. In this bath the skins remain four or five days, when they are thoroughly salted with sal-gem (or rock salt) alone (and not with salt and alum) after which they are fit to receive the dye, which for the red, is cochineal and alum, and for the yellow, pomegranate bark and alum. The skins are then tanned, dressed, suppled with a little oil, and dried.

Much excellent leather of every kind is prepared in different parts of the Russian empire. The preparation of the fine Russia leather, so well known for its quality and for its peculiar smell, is described at large in Mr. Tooke's

[b] Daniel's Rural Sports.

[c] Bulletin des Sciences, Repertory, vol. xi.

"View of the Russian Empire,"* to which we must refer the reader for the minuter particulars. In general it may be stated that the hides are first put into a weak alkaline lye to loosen the hair, and then scraped on a beam, then (if calves) are reduced by dogs dung, and a sour oatmeal drench, then tanned with great care and frequent *handling*. The bark used here is seldom oak, but, where it can be got, the bark of the black willow, or if this cannot be had, birch-bark. They are then dyed either red or black, these being the two colours the most esteemed. For the red the hide is first soaked in alum and then dyed with brazil wood. The black is given as usual with an iron liquor. The leather is then smeared with birch tar, which gives the peculiar smell so much prized (and which when used for book-binding has the valuable property of protecting the book from worms), and is finished by various other manipulations. The streaked or barred surface is given to the leather by a very heavy steel cylinder wound round with wires.

A valuable *Saffian* or dyed *Maroquin* leather, almost equal to that of Turkey, is prepared largely at Astracan and other parts of Asiatic Russia. Only bucks and goats skins are used for this purpose. The favourite colours are red and yellow. The general method of preparing the pelt is the same as in this country for the dyed Morocco leather, that is by lime, dog's dung, and bran. Honey is also used after the branning. The honey is dissolved in warm water, and some of this liquor is poured on each skin spread out on wooden trays till it has imbibed the whole of the honey, after which it is let to ferment for about three days, and then salted in a strong brine and hung up to dry. The skin is then ready to receive the dye, which for red is made with cochineal and the *salsola ericoides*, an alkaline plant growing plentifully on the Tartarian salt desarts, and the colour is finished with alum. When dyed, the skins are tanned with sumach. To the very finest reds a quantity of sorrel is used with the cochineal bath, and the subsequent tanning is given with galls instead of sumach, which renders the colour as durable as the leather itself. The roughness always observed on the surface of the skin is given by a heavy kind of iron rake with blunt points. The yellow saffians are dyed with the berries of a species of rhamnus (the Avignon berry would answer the same purpose, and is used in other countries) or with the flowers of the wild camomile.

That singular and valuable leather called *Shagreen* is a manufacture almost peculiar to Astrakan, where it is prepared by the Tartars and Armenians. For making shagreen only horses' or asses' hides are taken, and it is only a small part from the crupper along the back that can be used for this purpose. This is cut off immediately above the tail in a semicircular form, about 34 inches upon the crupper and 28 along the back. These pieces are first soaked in water till the hair is loose and is scraped off, and the skin, again soaked, is scraped so thin as not to exceed a wetted hog's bladder in thickness, and till all the extraneous matter is got out, and only a clean membranous pelt remains. The piece is then stretched tight on a frame, and kept occasionally wetted that no part may shrink unequally. The frames are then laid on a floor with the flesh side of the skin undermost, and the grain side is strewed over with the smooth black hard seeds of the *alabuta* or *goosefoot* (Chenopodium album) and a felt is then laid upon them, and the seeds trodden in deeply into the soft moist skin. The use of this is to give the peculiar mottled surface for which shagreen is distinguished. The frames with the seeds still sticking to the skin are then dried slowly in the shade till the seeds will shake off without any violence, and the skin is left a hard horny substance with the grain side deeply indented. It is then laid on a solid block covered with wool, and strongly rasped with two or three iron instruments (the particular form of which need not be here described) till the whole of the grain side is shaved, so that the impression of the seeds is very slight and uniform. The skins are then softened first with water, and then with a warm alkaline lye, and are heaped warm and wet on each other, by which means the parts indented by the impression regain much of their elasticity, and having lost none of their substance by paring, rise up fully to the level of the shaved places, and thus form the grain or granular texture peculiar to the shagreen. The skin is then salted and dyed.

The beautiful green dye is given by soaking the inner or flesh side of the skin with a saturated solution of sal-ammoniac, strewing it over with copper filings, rolling it up with the flesh-side inwards, and pressing each skin with a considerable weight for about twenty-four hours, in which time the sal-ammoniac dissolves enough of the copper to penetrate the skin with an agreeable sea-green colour. This is repeated a second time to give the colour more body.

* Vol. iii. p. 514.

Blue ſhagreen is dyed with indigo diſſolved in an impure ſoda by means of lime and honey. Black ſhagreen is dyed with galls and vitriol. The ſkins are finiſhed with oil or ſuet.

LEAVEN. See BREAD and FERMENTATION.

LEMONS, *Acid of.* See CITRIC ACID.

LEY or LEES, is uſually applied to any alkaline ſolution made by lixiviating pearl, or wood, or other aſhes that contain alkali.

Soap Lees is an alkali uſed by ſoap boilers, or potaſh or ſoda in ſolution, and made cauſtic by lime.

Lees of Wine are the refuſe or ſediment that depoſits from wine by ſtanding undiſturbed. See *Wine.*

LEPIDOLITE. *Lepidolith,* Wern. *Lepidolithe,* Broch.

Its colour is peach-bloſſom red paſſing into lilac-blue, alſo pearl-grey and yellowiſh-grey. It occurs in maſs, and diſſeminated in ſmall ſcales, reſembling mica. Its luſtre is gliſtening, ſomewhat paſſing into ſhining. Its fracture is fine-grained, uneven, paſſing on one hand into lamellar, and on the other hand into ſplintery. Its fragments are indeterminately angular ſharp-edged. It occurs in granular diſtinct concretions. Is tranſlucent in thin pieces; moderately hard, paſſing into ſoft; eaſily frangible. Sp. gr. 2.81—2.85.

Before the blowpipe it melts eaſily without intumeſcence into a white porous tranſparent enamel. At a high heat in a charcoal crucible it yields a pale grey, denſe ſemitranſparent hard glaſs, and loſes 17 per cent. of its weight.

Its analyſis was firſt undertaken by Klaproth, by whom it was found to contain,

Silex - - - - -	54.5
Alumine - - - - - -	38.25
Potaſh - - - - - -	4.
Oxyd of iron and manganeſe	0.75
	97.50
Loſs	2.5
	100.

A more accurate examination of this mineral was however ſubſequently undertaken by Vauqueling with the following reſult,

Silex - - - -	54.
Alumine - - -	20.
Fluat of lime - -	4.
Oxyd of manganeſe	3.
Ditto of iron - -	1.
Potaſh - - - -	18.
	100.

This mineral has hitherto been found only at Roſena, in Moravia, where it forms a thin bed in gneiſs.

LEUCITE. *Leuzit,* Wern. *Leucite,* Broch.

Its colour is yellowiſh, greyiſh, and rarely reddiſh white. It occurs in rounded or angular grains, or cryſtallized in ſolids of twenty-four faces, compoſed of two acute eight-ſided pyramids, ſet baſe to baſe, with the ſummits replaced by obtuſe four-ſided pyramids, the planes of which correſpond alternately with thoſe of the original pyramid. The cryſtals are always imbedded, and cryſtallized all round. The ſurface of the grains is rough, and for the moſt part dull; that of the cryſtals is ſmooth or ſlightly ſtreaked and gliſtening. Internally it is ſhining with a vitreous luſtre. The fracture is lamellar, paſſing to imperfectly and flat conchoidal. Its fragments are indeterminately angular ſharp edged. It varies from ſemitranſparent to opake. It is moderately hard, brittle, and eaſily frangible. Sp. gr. 2.46—2.49.

It is infuſible before the blowpipe without addition: with borax it gives a browniſh tranſparent glaſs; when expoſed to a ſtream of oxygen gas it melts eaſily into a whitiſh tranſparent glaſs.

It was firſt analyſed by Klaproth, and then by Vauquelin, with the following reſults,

	Klapr.		Vauq.
Silex -	54.	—	56.
Alumine	24.	—	20.
Potaſh -	21.	—	20.
Lime -	0	—	2
	99		98
Loſs	1		2
	100		100

Leucite occurs in lava, as well as in baſalt, and the other rocks of the lateſt trapformation. In baſalt it is for the moſt part vitreous, but in lavas it is opake and earthy. It is much leſs ſubject to decompoſition than the lavas in which it is contained, hence it occurs abundantly in looſe cryſtals in certain volcanic diſtricts: the road from Rome to Fraſcati in particular, is in many parts quite covered with them.

The lavas of Veſuvius and the baſalts of Italy abound in leucite; it alſo occurs in the baſalt and other congenerous rocks of Bohemia.

LEVIGATION is the reduction of any ſubſtance to an impalpable powder by rubbing on a flat marble, or other hard ſubſtance.

LICHEN. Several plants of this genus are known in technical chemistry as containing a quantity of mucilage in considerable purity. The extraction of this principle from the plant has lately been attempted by Lord Dundonald. See MUCILAGE.

LIDISCHERSTEIN. See KIESELSCHIEFER.

LIGNEOUS ACID. See ACETOUS ACID (*empyreumatic*).

LIGHT. The chemical properties of light are as yet but very imperfectly known, though there is great reason to believe that it is an agent of capital importance in many of the great chemical changes that are going on in the visible world, and even in the experiments of the laboratory its effects are often clearly demonstrable.

The process of rapid *combustion* is always attended with the evolution of light along with heat, the source of both of which is ascribed by Lavoisier to the oxygen which is known to be essential to combustion, so that according to this eminent philosopher whilst any substance is burning, the oxygen alone unites with the combustible substance, forming an oxyd, acid, &c. according to circumstances, and both the light and heat which previously existed in the oxygen are now set at liberty and appear in the form of visible flame.

But there are many weighty objections to this latter part of the hypothesis, which will be found under the articles *oxygen* and *combustion*, so that many chemists have returned to the old opinion that the light is derived from the burning body and not from the oxygen that supports combustion, an opinion which on the whole better agrees with the observed phenomena.

The sun's rays, the great source of light as well as heat to our world, have lately been found by Dr. Herschel to contain, besides all the common coloured rays, separable by the prism, a number of rays of mere heat, giving no light, still less refrangible than the red rays of the spectrum, and therefore extending beyond them, and producing a greater degree of heat than any of the visible rays. More lately it has been discovered, as appears both by Dr. Wollaston[a] and Mr. Ritter,[b] that beyond the opposite or violet side of the prism, are certain other rays, also invisible, which do not affect the thermometer, but which produce some of the chemical effects of the visible rays of light, particularly of the violet rays to which these are contiguous. These therefore appear to be (if the expression may be allowed) *invisible rays of light*, or rays which, though they do not illuminate, agree in chemical properties with those that do, and appear to be more than any other, separate from solar heat.

The most rapid and most unexceptionable chemical effect of pure light hitherto discovered, has been the change of colour of white luna cornea to a purplish-brown, or slate colour. This change takes place without requiring the least increase of temperature, or in any way being affected by heat or cold, and it occurs equally well in close as in open vessels, and only on the surface immediately exposed to the light. This change has been supposed to depend on a deoxygenation and incipient reduction of the submuriat of silver, but without being supported by any very unexceptionable experiments.

Some other anomalous chemical effects of solar light may be here mentioned. When the solutions of gold and silver, especially the former, are placed in contact with charcoal or with any other vegetable, or any animal matter, the metal is reduced totally or partially by exposure to the sun's rays, and the reducing substance is generally covered with a film of gilding or silvering. Count Rumford however has shewn that this effect is not exclusively owing to light, since it will take place in opake vessels when the temperature is raised to that of boiling water. In this way a bit of charcoal may be most beautifully spangled with gold or silver.

Light strongly tends to decompose liquid oxymuriatic acid, experience having shewn that to preserve it long it must be kept in a dark place or in opake bottles.

Light also renders pale nitric acid again ruddy and fuming to a certain degree, even though inclosed in vessels hermetically sealed.

Many of the vegetable acid salts, particularly the acetites, appear to be strongly affected by light, to become brown, turbid, and at last considerably decomposed.

A very great proportion of the natural dyes and colouring materials from the vegetable or animal kingdoms, have their brilliance of hue much impaired, and often entirely faded, by long exposure to the sun's rays, and hence the necessity of keeping fine tapestry, carpets, pictures, &c. as much as possible, out of the sunshine. The mode in which light operates here is totally unknown.

The crystallization of saline substances is remarkably affected by light, and there seems a strong influencing affinity between light and crystallization, so that during the crystallization

[a] Phil. Trans. for 1802. [b] Phil. Journ. 8vo. vol. iv. and viii.

of any ſolution, if the light be only partially admitted, the cryſtals will be much more numerous on the luminous than on the dark ſide, and often the whole maſs of cryſtals will radiate towards the luminous point. Solutions of moſt of the non-deliqueſcent ſalts, ſuch as carbonat of ſoda or nitre, when put in a glaſs veſſel, and abandoned to ſpontaneous evaporation, will form arboreſcent cryſtalline pellicles, that ſlowly travel up the empty ſides of the veſſel and gradually overtop it, and proceed down on the outſide. This proceſs always begins on the ſide the neareſt to the light, and is often entirely confined to it. Acetited lime exhibits this appearance in a very beautiful manner.

All ſolids and denſe liquids (not evaporable) become red and luminous at a certain temperature, which temperature is therefore deſcribed commonly as being a *red* heat. It appears however from a very ſimple and ſatisfactory experiment of Mr. T. Wedgwood,[c] that gaſes are not luminous, even at a very high heat, at which ſolids immerſed in them readily glow with a very bright red.

Whether any intenſity of heat would have this effect on gaſſes is doubtful.

Independently of the luminouſneſs produced by a high temperature, there is another kind of glow or phoſphoreſcence which a vaſt number of bodies exhibit, but in very unequal intenſity, either when the temperature is raiſed ſlightly, or by attrition, or by incipient chemical change. In the former inſtance it often appears totally unconnected with combuſtion or any other chemical phenomenon.

Some of the moſt important particulars on this curious ſubject will be mentioned under the article PHOSPHORESCENCE.

LIME. *Chaux*, Fr. *Kalk*, Germ.

Lime is an earth moderately hard, of a hot acrid taſte, ſoluble in water, though to a ſmall extent, producing nearly the ſame change on vegetable colour as the alkalies do, and ſtrongly promoting the fuſion of all earthy mixtures.

It is always prepared artificially by heating the various ſpecies of carbonats, till the carbonic acid is driven off, and it is made in very large quantities for the important purpoſes of mortars and cements of different kinds, for manure, and for other ſmaller uſes. The proceſs of lime-burning in the large way will be noticed in the following article.

For nice chemical purpoſes lime may be made by calcining in a full red heat for ſome hours either the white Carrara marble of the ſtatuaries, or oyſter-ſhells (the outer coat being firſt taken off). In both the lime is very conſiderably pure, that obtained from marble being only mixed with a ſmall portion of ſilex, and ſometimes with an atom of iron, and that from the ſhells containing only a little phoſphat of lime.

To obtain lime perfectly pure, let nitric or muriatic acid (free from iron) be quite ſaturated with fragments of white marble, leaving ſome of it for a time in the ſolution that only the lime may be taken up; add a little perfectly cauſtic ammonia to the ſolution, which will ſeparate any accidental impurity of iron or other earths but not the lime, then precipitate the lime in the ſtate of carbonat by carbonated ammonia, edulcorate the precipitate, and afterwards calcine it thoroughly. If the burning be done in an earthen crucible, too ſtrong a heat muſt not be uſed, as it would cauſe a portion of the lime to vitrify with, and adhere to the ſides of the crucible, but with a platina crucible any heat may be given.

Oyſter-ſhells will anſwer as well as marble, but the phoſphat of lime, taken up by the acid along with the lime, muſt be firſt ſeparated by pure ammonia.

The lime is known to be thoroughly calcined when, after being moiſtened with water, and reduced thereby to a ſoft pulp, it excites no efferveſcence with any acid moderately dilute. The portion that has begun to vitrify with the crucible remains hard and gritty, and will not mix with water.

The moſt known and remarkable phenomenon attending lime is the *ſlacking* with water. When a lump of well-burnt lime is dipped in water and removed after a ſecond or two, or otherwiſe wetted ſo as not to be drenched, the ſurface immediately dries, after which (a little ſooner or later according to the kind of limeſtone employed) it becomes very hot, ſwells, and cracks in every direction, and falls to pieces with a ſnapping noiſe and the evolution of a copious denſe ſteam, owing to the vaporization of the water by the intenſe heat generated. If a large quantity of very well burnt lime be ſlacked in the dark, flaſhes of light are alſo obſerved to come from it when breaking to pieces. The lime by this proceſs falls into a very fine dry impalpable powder, and when cold it will not again heat by more water.

In this ſtate it is called *ſlacked lime*, and it differs from *quick* or unſlacked lime, as appears,

[c] Phil. Tranſ. for 1792.

ſimply by containing water, and probably alſo by having parted with a large quantity of caloric, but it does not at this time contain any notable quantity of carbonic acid. Slacked lime dried at a heat of 600° contains, according to Lavoiſier, about 78 per cent. of lime and 22 of water. If ſlacked lime be diffuſed in more water it mixes uniformly with it by ſtirring, and forms a thick milky liquor, called by ſome *milk of lime*, but by repoſe all the lime falls to the bottom as a fine white ſediment, except a ſmall portion which the water diſſolves, forming *lime-water*.

Lime-water, when it has been ſome time at reſt, is always beautifully clear and tranſparent. It has a very ſtrong hot diſagreeable taſte, and changes vegetable colours nearly as the alkalies. The actual quantity of lime contained in lime-water however is very ſmall, not being more at the utmoſt than about $\frac{1}{550}$ of the ſolution, and often much leſs. When lime-water is expoſed to the air a white brittle pellicle preſently forms at the ſurface, which is the lime united with the carbonic acid, which it greedily attracts from the atmoſphere, and has thereby become inſoluble in the liquid. By degrees theſe pellicles fall down, and others ſucceed, till the whole of the lime has ſeparated and the water is rendered taſteleſs. Carbonic acid paſſed through lime-water makes it inſtantly turbid by the ſeparation of the calcareous carbonat, but this is again diſſolved, and the liquor again made perfectly tranſparent by uſing an exceſs of carbonic acid, as already explained under the article Earth of lime.

The lime has not yet been cryſtallized artificially. On account of its very ſparing ſolubility in water, it will not cryſtallize from the hot ſolution by cooling, like the watery ſolutions of barytes and ſtrontian.

Lime by itſelf will not fuſe in a leſs heat than that given by oxygen gas before the blowpipe, but it remarkably promotes the fuſibility of all earthy and ſaline compounds, and of metallic oxyds, as already explained, under the article Glass.

Hence it is often employed as a cheap and uſeful flux in the reduction of the refractory ores.

The uſe of lime as an eſſential ingredient in mortar and other cements has already been mentioned under the articles Cements and Lutes and Cements *(Calcareous)*.

Lime has a very powerful effect on vegetable and animal ſubſtances, but eſpecially the latter, breaking down their texture, and reducing them to a ſoft incoheſive pulp. It readily unites with oils when any calcareous ſalt is added to ſoap, and the white curdy maſs thus produced conſiſts of the oil united with the lime into an inſoluble compound.

The ſalts produced by the union of lime with the different acids will be mentioned under theſe acids reſpectively.

The ſeparation of lime from magneſia in analyſis is attended with ſome difficulty, and various ways have been propoſed. The commoneſt, and that which is employed occaſionally by Klaproth, where by other experiments it is made evident that no other earth or metal is preſent, is to diſſolve both earths in ſulphuric acid, and after evaporation to thorough dryneſs, bring the mixture to a low red heat: the affuſion of *cold* water will then diſſolve out the ſulphat of magneſia with ſcarcely any portion of ſulphat of lime, after which the magneſian ſalt may be decompoſed by an alkaline carbonat and ſeparately eſtimated according to its known proportions.

Another way of eſtimating lime ſeparately is founded on the property which ammonia has (when quite cauſtic) of precipitating all the other earths and the oxyd of iron from their acid ſolutions; by which method the lime alone will be left in ſolution. But if phoſphat of lime is preſent the ammonia will precipitate it though it will not decompoſe it, which therefore may lead to an error.

Alſo if a mixture of lime and magneſia, both perfectly decarbonated, be boiled with a ſolution of carbonat of potaſh, the lime alone will become carbonated and by then thoroughly waſhing the reſidual earths, conſiſting of the carbonat of lime and the pure magneſia, and adding a ſtrong acid, the carbonic acid will be diſplaced from the carbonat of lime, and the quantity of lime may be thus eſtimated from the known proportions of this carbonat.

Mr. Tennant has adopted another method in his analyſis of the magneſian lime-ſtone. He diſſolves both earths in muriatic acid, then dries the mixture and heats for a few minutes to redneſs, by which means the muriatic acid is driven off from the magneſia but not from the lime. The quantity of magneſia is then eſtimated by the quantity of freſh muriatic acid required again to diſſolve it, whence by calculations eaſily made the reſpective quantities of the two earths may be inferred.

For the habitudes of lime when in ſolution along with *alumine*, ſee that article.

The order of the affinities of lime with the

respective acids is as follows: the oxalic, sulphuric, tartaric, succinic, phosphoric, nitric, muriatic, fluoric, arsenic, lactic, citric, benzoic, sulphureous, acetic, boracic, carbonic, and prussic acids.

LIME *Water*, *Cream and Milk of*. (See the preceding article.)

LIMESTONE.[a] *Kalkstein*, Wern. *Chaux Carbonatée* (in part), Hauy.

This species may be divided into the five following families.

1. *FAM.* Foliated.

1. *Subsp.* Calcareous spar. *Common Spar*, Kirw. *Kalkspath*, Wern. *Spath calcaire*, Broch.

Its principal colour is white, either greyish, greenish, yellowish, or rarely reddish; the other colours that it presents are leek and olive green; honey, ochre, wine, and wax yellow; flesh-red, brownish-red, and very rarely rose-red; smoke-grey passing into black; greenish and yellowish-grey, and very rarely pearl-grey and light violet-blue. On the surface of the lighter coloured crystallized varieties is often observed a segment of a circle of iridescent colours. It occurs massive, in veins, disseminated, in globular and kidney-shaped pieces, in druses, and crystallized. Its primitive figure is an obtuse rhomboid, the alternate plane angles of which measure 101° 30′ and 78° 30′. Besides this it presents a vast number of varieties of which the following are some of the more remarkable.

1. A very obtuse rhomboid, the plane angles of which measure 114° and 66°.

2. An acute rhomboid, the plane angles of which measure $75\frac{1}{2}$ and $104\frac{1}{2}$.

3. A dodecahedron with scalene triangular faces, composed of two six-sided pyramids, joined base to base, so that the line representing their common base forms three saliant and as many re-entering angles.

4. An acute rhomboid, the plane angles of which measure $45\frac{1}{2}$° and $134\frac{1}{2}$°.

5. A still more acute rhomboid than the preceding, the plane angles of which measure $37\frac{1}{2}$° and $142\frac{1}{2}$°.

6. An acute, almost cubic, rhomboid, the plane angles of which measure 88° and 92°.

7. The primitive form, the two summits of which are intercepted by two triangular faces.

8. The same as var. 2. with the edges composing the two summits, replaced by narrow pentagonal planes.

9. The primitive form, with a strait six-sided prism, interposed between the two pyramids of which it may be considered as composed: hence all the faces are rhombs.

10. The same as var. 3. with each summit intercepted by three rhombic faces, parallel to those of the primitive nucleus.

11. The primitive form with a strait prism interposed between the two pyramids in the direction of the lateral solid angles of the rhomboid: hence all the faces are pentagons.

12. An acute-rhomboid composed of the primitive form and that of var. 5. The plane angles surrounding the two summits are equal to the acute ones of the primitive form; all the other plane angles are those of var. 5.

13. A regular hexahedral prism.

14. A rhomboid, approaching very nearly to a cube, with the two summits replaced by triangular planes.

15. The same as var. 4. with the two summits replaced by triangular planes.

16. The same as var. 1. with a strait six-sided prism intervening between the two pyramids.

17. The same as var. 1. with an intervening prism in the direction of the lateral solid angles.

18. The preceding, in which the prism is so far suppressed as to form only six adjoining triangular faces.

19. The same as var. 17. except that the long sides of the faces of the prism, instead of being parallel, approach towards each other at that extremity which is terminated by a single line.

20. A dodecahedron like var. [illegible] acute, each of the summits of [illegible] placed by a pyramid composed [illegible] ziums.

21. The same as var. 3. the [illegible] gles of which are replaced by as many trapezoidal or lengthened hexagonal faces.

22. The same as var. 4. but bevilled on the edges contiguous to the summits.

23. The same as var. 21. with each of the summits replaced by three rhombic faces parallel to those of the primitive nucleus.

24. The same as var. 17. with the extremity of the terminal pyramid replaced by a horizontal equilateral triangular plane.

25. A six-sided prism with dihedral summits; the sides of the prism are acute-angled triangles, the apexes of which are alternately directed towards each extremity.

26. A dodecahedral prism.

[a] Emmerling, Brochant, Hauy, Kirwan, Jameson.

27. The same as var. 3. except that the lateral solid angles are replaced by irregular pentagons, and three of the alternate edges surrounding each summit are replaced by narrow parallelipipeds.

28. The lenticular calcareous spar, which is a modification of var. 11. produced by the flattening of the lateral edges, into a single curved line, and the total or partial suppression of the terminal edges, whence results a convex solid resembling a lens.

The crystals of calcareous spar are variously aggregated and often deeply imbedded; hence the rhomboidal crystals, especially the more acute ones present only trihedral pyramids, the three other faces that complete the rhomboid not appearing above the substance in which the crystals are engaged. The size of the crystals varies from $\frac{1}{10}$ of an inch or less to 12 or 14 inches in length; the dodecahedron var. 3. affords generally the largest crystals. The lateral planes of the crystals are commonly smooth and splendent.

The internal lustre varies from nearly specular to glistening, and is vitreous, inclining sometimes to pearly. Its fracture is strait and very rarely curved lamellar. It is easily divisible in three directions, and the form of its fragments is always rhomboidal. When in mass, calcareous spar occurs in large and coarse-grained distinct concretions, also in testaceous, wedge-shaped, and diverging, prismatic distinct concretions.

The transparency both of the massive and crystallized varieties is subject to much variation; in general however the crystals are transparent and semi-transparent, and the others are semitransparent and translucent. When transparent it possesses a double refraction in a remarkable degree. In hardness it ranks between gypsum and fluor spar. It is brittle, and very easily frangible. Sp. gr. 2.69—2.72.

Certain varieties of calcareous spar, especially those from Derbyshire, become phosphorescent when laid on a hot coal.

Calcareous spar dissolves with effervescence in almost every acid, and by exposure to the blowpipe for some time it is reduced to quicklime. Most of the varieties contain a small variable proportion of iron, but the iceland spar, which is purest of all, consists only of lime, carbonic acid, and water, in the following proportions:[b]

Lime - - -	55.5
Carbonic acid -	44.
Water - - -	0.5
	100.0

Calcareous spar occurs in veins in almost every kind of rock, from the oldest granite, even to the alluvial strata. It accompanies a great variety of minerals, and is almost the constant concomitant of galena.

It is so generally distributed that a list of localities would be useless: the rarest and most beautiful crystals come from Derbyshire and Cumberland, in England; from Saxony, France, Spain, and Iceland. The double refracting Iceland spar may be considered as the purest form of calcareous spar; it appears in our cabinets in the form of rhomboidal prisms, but these are produced by the fracture of large dodecahedral crystals of var. 3.

2. *Fam.* Granularly foliated.

2. *Subsp.* Statuary marble. Granular marble. Primitive Limestone. *Körniger Kalkstein*, Wern. *Pierre calcaire grenue*, Broch. *Chaux carbonatée saccharoide*, Hauy.

Its usual colour is snow-white, yellowish, greyish and greenish white, rarely reddish-white: it also occurs bluish, greenish, ash and smoke grey, and greyish-black; from reddish-white it passes into pearl-grey and flesh-red, and from greenish-white into yellowish and olive green. Its colour is generally uniform, but sometimes it presents clouds, spots, or veins. It is always in mass. Its lustre varies from shining to glimmering, and is intermediate between pearly and vitreous. Its fracture is minutely foliated passing into splintery. Its fragments are indeterminately blunt edged. It generally occurs in granular distinct concretions; when these are very fine the fracture approaches nearly to compact. It is translucent, and the less so, as it is the more loaded with colouring matter. In hardness it is nearly equal to the preceding; it is brittle and easily frangible. Sp. gr. 2.7 to 2.8.

In chemical characters it agrees with calcareous spar.

It occurs sometimes in mountain masses, but more frequently in beds in mountains of gneiss, and argillaceous and micaceous schistus: when in gneiss the concretions are very distinct, but when it occurs in transition rocks the concretions are hardly visible. It frequently contains

[b] Phillips in Phil. Mag. xiv. p. 290.

other ſubſtances diſperſed through its ſubſtance, ſuch as mica, hornblende, actynolite, aſbeſt, quartz, ſerpentine, galena, blende, iron pyrites, and magnetic iron-ſtone.

The moſt valuable variety of ſtatuary marble is the ſnow-white; that of the iſle of Paros in the Archipelago has ſupported undiminiſhed the high reputation which it appears firſt to have derived from the ſculptors of Greece, almoſt all their fineſt works having been formed of this material. Next in eſteem is the white marble of Carrara in Italy, which is employed in moſt of the finer works of modern ſtatuary. Of the coloured varieties of primitive limeſtone that of the iſland of Tiree, on the weſtern coaſt of Scotland, deſerves perhaps the higheſt place, its colour is a bright fleſh-red, beautifully relieved by interſperſed cryſtals of green hornblende; its fracture is almoſt ſplintery, and it is ſuſceptible of a high poliſh.

3. *Subſp.* Dolomite, (which ſee.)

3. *FAM.* Fibrous.

4. *Subſp.* Satin ſpar. *Common fibrous limeſtone*, Jameſon. *Gemeiner faſriger kalkſtein*, Wern.

Its colour is greyiſh, yellowiſh, or reddiſh white; it occurs in maſs. Its luſtre is between ſhining and gliſtening with a pearly or ſatiny luſtre. Its perpendicular fracture is ſtrait or waved parallel fibrous, the fibres are either fine or coarſe; the croſs fracture is compact ſplintery. Its fragments are ſplintery or flattened fibrous. It is tranſlucent, and in thin pieces is ſemitranſparent. Its hardneſs is a little inferior to that of calcareous ſpar, it is brittle, and eaſily frangible. Sp. gr. 2.7.

In its chemical characters it reſembles calcareous ſpar. Its conſtituent parts, according to Mr. Pepys,[c] are

Carbonic acid	-	47.6
Lime - -	-	50.1
Water and loſs	-	2.3
		100.0

It occurs in ſtrata from one to four inches thick, and is traverſed by veins of pyrites.

The moſt beautiful is found in Derbyſhire: it is ſuſceptible of a fine poliſh, and is employed in inlaying, and in the manufacture of ſmall ornaments in imitation of pearl.

5. *Subſp.* Stalactite or ſinter. *Kalkſinter*, Wern.

The colour of ſtalactite is ſnow-white, greyiſh, greeniſh, and yellowiſh white; alſo wax and honey yellow and yellowiſh-brown; alſo yellowiſh, browniſh, or bluiſh green, or mountain-green; ſometimes though rarely fleſh or peach-bloſſom red. The colour is either uniform or in ſtripes.

It occurs maſſive, reniform, botryoidal, tabular, ſtalactite, and tuberous. Externally it is rough and often druſy. Internally it has a glimmering pearly luſtre. Its fracture is fibrous, more or leſs divergent, often completely radiated. Its fragments are indeterminately angular, or wedge-ſhaped. It generally occurs in curved lamellar diſtinct concretions, parallel with the external ſurface. It is more or leſs tranſlucent paſſing into ſemitranſparent. Its hardneſs is equal to that of calcareous ſpar. It is brittle, and eaſily frangible.

It forms ſtalactites, and various rounded projections in the caves and hollows that ſo frequently occur in limeſtone. The Grotto of Antiparos, the Woodman's Cave in the Hartz, Caſtleton Cavern, and other caverns in Derbyſhire, Yorkſhire, &c. afford abundant ſpecimens of this mineral. Some caverns have been entirely filled by it, ſo that it is occaſionally obtained in large maſſes. In this ſtate it is called oriental alabaſter, and is much employed by the ſtatuary.

That beautiful coralloidal ſubſtance, the flos ferri, is commonly ranked among the calcareous ſtalactites. It has never been analyſed, but from its only occurring in veins of ſpathoſe iron ore, it probably contains a large proportion of carbonated iron.

4. *FAM.* Compact.

6. *Subſp.* Common limeſtone, *Gemeiner dichter kalkſtein*, Wern. *Pierre calcaire compacte commune*, Broch.

Its uſual colour is ſome ſhade of grey, either yellowiſh, bluiſh, or ſmoke-grey: from aſh-grey it paſſes into greyiſh-black, from yellowiſh-grey into yellowiſh-brown and ochre-yellow: it alſo ſometimes, though rarely occurs blood-red and fleſh-red, and greeniſh-grey. Two or more colours often exiſt in the ſame piece in the form of veins, zones, bands, ſtripes, clouds, and dots: the ſurfaces of the ſtrata and of caſual rents are often covered with black or brown arborizations. It is uſually maſſive, but alſo exhibits a variety of external ſhapes. Internally it is dull, yet often contains ſhining particles that appear to be cryſtalline laminæ. Its uſual fracture is fine ſplintery, but it paſſes into flat conchoidal, uneven, and earthy, ſometimes though rarely it is ſlaty. Its fragments

[c] Phil. Mag. xii. p 367.

are indeterminately angular, more or less sharp-edged. It is translucent on the edges, moderately hard, brittle, and frangible. Sp. gr. 2.6—2.7.

It dissolves in acids with a vigorous effervescence, and when exposed to the blowpipe is converted into quicklime. It is composed of lime and carbonic acid, with a small and variable proportion of silex, alumine, the oxyds of iron and manganese, and inflammable matter.

Limestone sometimes, though rarely, occurs among the transition rocks, in which case it alternates with and rests upon slate, and has a splintery fracture, and is for the most part destitute of the remains of organized bodies.

But the principal repository for limestone is the class of secondary or floetz mountains. Among these it always occurs in strata, constituting several distinct formations: the oldest of these is that which rests upon the red sandstone, and bituminous marl slate. Some of the other formations are characterized by the shells with which they abound. Of these the least recent contain ammonites, belemnites, gryphites, and turbinites, while the most modern contain various present marine shells and fish. Limestone ranks among the metalliferous mountains: the ores which are deposited within it are galena and blende, more rarely fahlerz and malachite. It frequently also alternates with thin seams of hornstone or chert, as chalk does with flint.

Limestone when unburnt is used for building and paving stones, and when hard and compact enough to admit of polishing it is employed under the name of marble, in the more ornamental parts of architecture; when deprived of its carbonic acid, or in the state of quicklime, it forms the base of all the calcareous CEMENTS, and is largely employed by the farmer for manure, by the tanner, the soap-boiler, the calico-printer, &c. and by the smelter to facilitate the reduction of the more refractory ores.

The argillaceous limestones have for the most part a tendency to a slaty fracture, and pass into marl; their colour is principally bluish-grey or reddish, and they are readily decomposed by the action of the air; the mortar into which this variety of limestone enters possesses the quality of hardening under water, as is mentioned at large in the article CEMENT.

7. *Subsp.* Magnesian Limestone.[d]

This substance was confounded with common limestone till Mr. Tennant undertook an examination of it; and although the external distinctive characters between the present subspecies and common compact limestone have not hitherto been laid down by any author, yet the chemical differences in the composition of the two clearly require their division into distinct subspecies. When deprived by heat of its carbonic acid it is much longer in reabsorbing it from the atmosphere than common limestone is. Mortar made of the former and employed in the outside of a building, in the space of eight years, had recovered only 47 per cent. of the carbonic acid originally contained in the stone, whereas mortar of common limestone in a year and three quarters had regained 63 per cent. of its original amount of carbonic acid. The great length of time which this magnesian limestone continues caustic is the cause of a most important difference between this and common limestone with regard to their employment in agriculture: lime of the former description is technically called *hot*, and when spread upon land in the same proportion as is generally practised with the latter, greatly impairs the fertility of the soil, and when used in a somewhat larger quantity entirely prevents all vegetation. The habitudes of the two subspecies, with regard to their solution in acids, are also different, in the same manner as dolomite differs from granular marble, the magnesian limestone being much more slowly soluble than the other.

It occurs in strata at Bredon-hill, near Derby; at Matlock in the same county. In the counties of Yorkshire and Nottinghamshire it extends from near Worksop to the vicinity of Ferrybridge, a distance of above thirty miles. It is also common in Northumberland. The Minster and city walls of York, and Westminster-hall in London, are built of it. It sometimes though rarely contains shells, and appears to rest upon secondary limestone.

According to Mr. Tennant's analysis it contains from

20.3	to	22.5	Magnesia.
29.5	—	31.7	Lime.
47.2	—	——	Carbonic acid.
0.8	—	1.2	Clay and oxyd of iron.

5. *Fam.* Granular.

8. *Subsp.* Roestone. *Roogenstein*, Wern. *Oolite*, Broch.

Its colour is hair and chesnut brown, or yellowish-brown, or ash-grey. It occurs in mass, and is without lustre. It is composed of small and fine-grained globular distinct concretions;

[d] Tennant in Phil. Trans.

hence its fracture in the great is granular, but that of each diſtinct concretion is fine ſplintery. Its fragments are indeterminately angular, blunt-edged. It is opake paſſing into tranſlucent on the edges. It is conſiderably ſofter than common limeſtone. It is brittle, and very eaſily frangible. Sp. gr. 2.45—2.55.

It occurs in beds interpoſed between ſandſtone, common limeſtone, and gypſum.

The Ketton-ſtone of England belongs to this ſubſpecies, as alſo does the Portland ſtone. It is found alſo in Sweeden, Swiſſerland, and eſpecially in the province of Thuringia, in Saxony.

It is uſed for building, and as a manure, eſpecially when broken down by expoſure to the air: but is not burnt into quicklime on account of the clay with which it is intimately mixed.

It has obtained its preſent name from the reſemblance which many of its varieties bear to the roe of fiſh; indeed it was formerly ignorantly ſuppoſed to be this very ſubſtance petrified.

9. *Subſp.* Peaſtone. *Erbſenſtein*, Wern. *Pierre de pois*, or *piſolite*, Broch.

Its uſual colour is yellowiſh-white, whence it paſſes on one hand to ſnow-white, and on the other to light yellowiſh-brown. It occurs in maſs, but when it forms the lining of cavities it is then reniform or botryoidal. Internally it is dull: its fracture is difficult to determine, but appears to be even: its fragments are indeterminately blunt-edged. It is compoſed of ſpheroidal diſtinct concretions either coarſe or ſmall, and theſe are again compoſed of thin concentric curved lamellæ. It is opake, ſoft, and eaſily frangible.

It occurs in conſiderable maſſes near the hot ſprings of Carlſbad, in Bohemia, and appears to be a depoſit from theſe fountains. The centre of each concretion is uſually a grain of ſand, but ſometimes a ſmall cavity filled with air. It is alſo ſaid to occur in Hungary, and at Perſcheeſberg in Sileſia.

On Marble.

In the language of the ſtatuary and architect all ſtones come under the name of marble that are harder than gypſum, occur in conſiderable maſſes, and are capable of a good poliſh.

Hence, not only many varieties of limeſtone, but alſo granite, porphyry, ſerpentine, and even the fine-grained baſalts, are called marble. Among mineralogiſts however the term is uſed in a more reſtricted ſenſe, being confined to thoſe varieties of dolomite, ſwineſtone, and compact and granularly foliated limeſtone that are capable of receiving a conſiderable poliſh. Of theſe calcareous marbles the moſt valuable for hardneſs, durability, and colour, are procured from Italy, from the Greek iſlands, and from Syria: the ancient Romans, when at their height of civilized luxury, alſo obtained from Numidia and other diſtricts in Africa ſome highly-eſteemed varieties of marble.

The white granularly foliated limeſtone has always been the favourite material of the ſculptors of ancient Greece and modern Europe, both on account of its pure colour, its delicate tranſlucence, and its granular texture, which renders it much more eaſy to work than compact limeſtone. Dolomite poſſeſſes ſimilar advantages, and is ſomewhat ſofter and of a finer grain: ſeveral of the ſmaller works of the Greek ſculptors are of this material. The two great ſources whence the ſtatuary marble of Europe has been procured are Paros and Carrara. The Parian marble is the pureſt, conſiſting of hardly any thing elſe than carbonat of lime; hence it is ſofter, ſomewhat more tranſparent, and of a more viſibly laminated texture than that of Carrara, which is mingled, often in conſiderable proportion, with granular quartz.

The moſt eſteemed of the architectural marbles are the following.

1. A deep blue-coloured marble, called bardiglio, from Carrara, which appears to differ only in colour from the white ſtatuary marble of the ſame place.

2. Cipolin marble, which is ſtatuary marble traverſed by veins of mica.

3. Lumachelle marble, which is a ſecondary compact limeſtone of a grey or greyiſh-brown colour, holding ſhells that ſtill retain their pearly luſtre. The fire marble of Bleyberg, in Carinthia, is the moſt valuable of this variety; the baſe is a greyiſh-brown compact limeſtone, in which are implanted ſhells of a fire colour and beautiful irideſcent luſtre.

4. Florentine marble, which is a compact very argillaceous limeſtone, of a grey colour, with deſigns of a yellowiſh-brown repreſenting architectural ruins.

5. The yellow marbles of Syria, Sienna, and Arragon.

6. The green marbles known by the names of campan, verde antiche, verde di Corſica, &c. which are mixtures of granularly foliated limeſtone, calcareous ſpar, and ſerpentine, with threads of aſbeſtos.

7. A very rich breccia, called brocatelli, con-

taining small fragments of yellow-red and purple limestone, cemented by semitransparent white calcareous spar.

Of the marbles that the British islands produce that of Tiree deserves the first place; and if its colours were not apt to fade, it might rank among the most beautiful even of Italy. The counties of Devonshire and Derbyshire also afford several varieties of considerable beauty, though by no means to be compared with the most esteemed of Italy and Spain.

On Limestone.

Although all the species with their varieties that are described in this article may, properly speaking, be called limestone, since they consist almost entirely of calcareous carbonat, and may by burning be brought to the state of quicklime, yet we shall find in fact that the substances belonging to the family of *compact* limestone are the only ones that are or that can be advantageously employed for this purpose in the large way. Sometimes calcareous spar and, more frequently, statuary marble, are used in the laboratory for the purpose of procuring a lime purer than ordinary for the purposes of chemistry. But owing to the crystalline texture of these substances, the laminæ, of which they are composed, part from each other during the volatilization of their carbonic acid, so that by the time when they are rendered thoroughly caustic their cohesion is destroyed, and they are reduced nearly to the consistence of sand, a circumstance which must always prevent them from being used in kilns of the common construction. The limekiln at present almost universally employed in this country is a cup-shaped concavity in a solid mass of masonry, open at the top, and terminated at the bottom by a grate, immediately above which is an iron door that may be opened and closed at pleasure. This simple furnace is first charged with fuel (either wood or coal, but more commonly the latter), upon which is afterwards laid a stratum about a foot thick of limestone, broken into pieces not larger than the fist: to this succeeds a charge of fuel, and so on alternately, keeping the kiln always full. The pieces of limestone descend towards the bottom of the kiln, in proportion as the fuel is consumed, being in the mean time kept at a pretty full red heat. At this temperature the water and carbonic acid are driven off, and by the time that the limestone arrives at the bottom of the kiln, which happens in about 48 hours, it is rendered perfectly caustic. The door above the grate is then opened, and all the lime below the next descending stratum of fuel is raked out: the remaining contents of the furnace sink down, and a fresh charge is laid on at top. The compact limestone, after having undergone this process, though much lighter and porous than before, still retains its figure unaltered, hence it is readily separable from the ashes of the fuel, and is sufficiently hard to be carried from place to place without falling to pieces. For some further remarks on the different varieties, see CEMENTS CALCAREOUS.

LINSEED-OIL. See OILS, FIXED.

LIQUATION, or *Eliquation*. This process will be described under the article *Silver*.

LIQUOR OF FLINTS, or *Liquor silicum*. This term has been given to the solution of silex in a fixed alkali, and dissolved in water. See SILEX.

LIQUOR OF LIBAVIUS. See TIN.

LIQUOR (*Boyle's fuming*). See SULPHURET *of Ammonia*.

LITHARGE. See LEAD.

LITHIC *Acid*, or *Uric Acid*. See URINARY CALCULI.

LITHOMARGA. See STEINMARK.

LITMUS or *Archil*. *Orseille*, *Tournesol*, Fr. This beautiful but perishable dye is a violet red paste, prepared from a species of lichen, which grows abundantly in the Canary Islands, in the South of France, and in some other parts. Many other species of lichen have also the property of assuming a beautiful purple, when prepared in the same manner as litmus.

Archil, by which name it is better known in commerce, is generally in the form of cakes like anotta, which are prepared largely in Holland, and in London, for the use of the dyers.

The Dutch process has long been concealed as much as possible, but it is known to be effected by fermenting the moss or lichen, and adding alkalies and urine. The following is given as the exact process.[a] The lichen is first dried, cleansed, and reduced to powder in a mill like the oil-mill. The powder is then thrown into a trough with one half its weight of pearl-ash, and moistened with a little human urine, and allowed to ferment. This fermentation is kept up for some time by successive additions of urine till the colour of the materials changes first to red and then to blue.

When in this state it is mixed with a third of its weight of very good potash, and spread upon deep wooden trays till dry. A quantity of

[a] Journ. du Commerce, or Nich. Journ. 4to. vol. ii. p. 311.

chalk is added at laſt, apparently with no other object than to increaſe the weight.

There are ſeveral other kinds of moſs or lichen, which will aſſume by a ſimilar preparation the rich colour of the true archil, which is a crimſon tending to violet, and have occaſionally been employed for the ſame purpoſes in dyeing.

The colour of archil is readily extracted by water or by alcohol. The colour of the watery ſolution, or of any ſubſtance dyed with it, ſoon fades by expoſure to air, and hence it is uſed to give a gloſs or finiſh to the deeper and more permanent colours. It is much employed for this purpoſe in the dyeing of ſilk, ſtuffs, and ribbons.

All acids and ſalts with exceſs of acid, ſuch as alum or tartar, change the natural violet-purple of litmus to red; and this change is effected ſo readily and perfectly with a very ſmall degree of acidity, as to render this colour a valuable teſt to the chemiſt, to detect the preſence of uncombined acids. Even the carbonic acid in ſo ſmall a proportion as that in which it exiſts in the breath (or about 5 or 6 per cent. of the bulk of the air expired) may be made to change the colour of litmus infuſion, if a little of it diluted ſo that the purple-blue is ſcarcely viſible, be ſhaken in a phial containing air expoſed from the lungs. It is probable too on account of the carbonic acid from the atmoſphere, that paper or any thing elſe tinged with litmus reddens before the colour is altogether loſt.

When reddened by an acid, the blue is reſtored by an alkali, and thus litmus may be made a teſt both of acid and of alkali.

None of the known mordants appear to have any effect in rendering the dye of archil leſs periſhable, except perhaps the ſolution of tin, but this being always acid, alſo changes the colour, ſo that the fine purple-blue is equally loſt.

Marble ſoaked with litmus liquor imbibes it in ſome days, and becomes beautifully tinged in this method, and the colour will remain for a conſiderable time unimpaired.

LIVER OF ANTIMONY. See ANTIMONY.

LIVER OF ARSENIC. See ARSENIC.

LIVER OF SULPHUR. See SULPHURET.

LIXIVIUM. This term ſignifies nearly the ſame as LEY.

LOADSTONE. See IRON (*Ores of*).

LOGWOOD, or CAMPEACHY WOOD. *Bois d'Inde*, Fr.

The tree that furniſhes this wood (the *Hæmatoxylum Campechianum*) grows to a very large ſize in various parts of the Weſt-Indies, and eſpecially on the Bay of Campeachy and along the American continent, and is imported largely into this country from Jamaica for the uſe of the dyer. It uſually comes over in moderate ſized logs, of a very dark violet-brown colour, very hard and heavy. Before it is uſed it is broken down or raſped in powerful mills into fine chips.

The taſte of logwood is mildly and agreeably aſtringent, and when long chewed it leaves a pleaſant ſweetneſs in the mouth. Both water and alcohol take up a conſiderable part of the ſoluble portion of the wood (alcohol much more than water), and thereby become tinged of a deep purple-red or brown.

Acids added to the watery decoction turn it yellow, but alkalies give a very deep purple colour, but without forming any precipitate.

Alum added to the decoction of logwood cauſes a violet precipitate or *lake*, and the ſupernatant liquor alſo remains violet, and gives a freſh portion of lake on the affuſion of an alkali.

The ſalts of iron give an inky black with all the ſolutions of logwood, under the ſame circumſtances as with galls, as explained under the article *Iron*, whence the preſence of gallic acid in logwood is proved.

The ſolutions of tin fo[illegible] a very fine violet or plumb colour lake with [illegible] log-wood, and totally precipit[illegible] ter, ſo that the ſupernat[illegible] and colourleſs.

Logwood is uſed in dyeing, [illegible] own natural purple (with ſeveral ſhades [illegible] variations according to the mordant uſed) or to heighten and improve the common black with iron and galls. It is found in this latter method to give a peculiar gloſs and luſtre which renders it a very valuable dyeing material.

LUNA CORNEA is that white curdy precipitate of muriat of ſilver which takes place when the nitrat, acetat, or any other ſoluble ſalt of ſilver comes in contact with muriatic acid, either ſingle or in any ſoluble combination. See SILVER.

LUNAR CAUSTIC is nitrat of ſilver evaporated to dryneſs, melted in a heat juſt below redneſs, and immediately poured into moulds, by which it is reduced to hard black cylinders, about the ſize of common ſlate-pencils.

In this ſtate it is in frequent uſe in ſurgery as one of the beſt cauſtics hitherto known for

most purposes. It differs from the crystallized nitrat in having lost both its water of crystallization and also a small portion of the acid.

LUTE. See the article CEMENTS and LUTES.

LYMPH. This is generally understood to be a clear liquid, transparent and colourless as water, which is found abundantly, but with several modifications, in various parts of the animal body. It is particularly distinguished into *watery* and *coagulable* lymph. The former (of which the tears are an example) is little else than water holding in solution a very minute portion of salt, and still less of animal matter. Coagulable lymph, which is often found in great quantity and perfection in encysted dropsy, contains also a very considerable portion of albumen so as to be viscid to the touch, and when heated to coagulate firmly like the white of egg.

M

MACERATION means nearly the same as *Infusion*.

MACLE. Chiastolith, *Karsten*. Macle basaltique, *Hauy*.

This mineral is composed of two distinct substances, one of which is of a yellowish-white or dirty grey colour, the other is greyish-black passing to bluish-black. It occurs crystallized in the form of quadrilateral and nearly rectangular prisms. The summit of these prisms is always truncated, which gives an opportunity of observing the regular symmetrical disposition of the two substances of which it is composed. The white part forms the exterior of the prism, within which is a dark-coloured prism, exactly parallel to that by which it is inclosed. From each of the angles of the interior prism there proceeds a black line or thread bisecting the corresponding angle of the white prism; sometimes also at the extremity of these lines, and consequently adjoining the four angles of the exterior prism, are formed as many very thin black prisms: the black part is usually the most abundant. The crystals are small or middle-sized, much elongated, and always imbedded. The white part is externally glistening; internally possesses a slight greasy lustre; the black part is at most slightly glimmering. The fracture of the white part is lamellar, often imperfectly so, in two directions parallel to the faces of the prism. That of the black part is earthy. Both the one and the other are somewhat unctuous to the touch. It gives a white powder; is soft, passing to moderately hard, and not very brittle. Sp. gr. 2.94.

On exposure to the blowpipe the white part of the macle gives a white scoria, and the black part a black glass.

The most perfect specimens occur in France, near St. Brieux in Brittany, imbedded in argillaceous schistus. It is also found near Bareges in the Pyrennees, also imbedded in primitive argillaceous schistus: specimens are also to be met with at San Jago of Compostella.

MADDER. *La Garance*, Fr. [*]

The plant which furnishes this most valuable material in the art of dyeing (*Rubia Tinctorum*, Linn.) grows wild in most parts of the South of Europe, and in many parts of the Levant, and is cultivated very largely in the more northern counties, particularly in Holland, in the province of Zeeland, which has long been celebrated for producing this article in very great perfection. The madder plant grows to about three feet in height, and has a large long spreading fibrous root of a very deep red colour, which is the part used in dyeing.

The Levantine madder (called *Lizari* or *Azala*) has somewhat of a higher and finer colour than the Dutch, but the latter is prepared with more care in the subsequent drying and sorting.

The madder roots as soon as they are gathered are thus prepared in Holland. They are first put under a shed, or granary, or other sheltered place, where they remain in a free current of air for ten or twelve days till they are quite pliable, and till on squeezing them no juice can be pressed out. The drying is then hastened by removing them either into a common oven where the heat is slack, when the quantity of madder is but small, or else into large stoved rooms built for the purpose, and heated with turf, with a large opening for the free exit of all the vapours within. Much care and very nice manipulation seems requisite to perform this process in its utmost perfection. When the roots are quite hard and brittle they are laid on a threshing floor and slightly beaten with the flail to separate the dirt and outer thin skin, after which they are ground in a mill and the powder sifted, sorted, and packed carefully in large barrels, in which state it is exported, and used by the dyers.

The method practised in Turkey and Persia to prepare the madder used in the beautiful

[*] Encycl. Art. Garance. N. Dict. d'Histoire Naturelle.

Adrianople red (described under the article DYEING), is stated by Althen, an eye-witness to be the following: for every hundred weight of the fresh root a steeping liquor is prepared of two pounds of bran, and one pound of honey and alum in four gallons of water. The roots well washed and cleaned are then soaked with this liquor for two or three days, after which they are dried first under cover, and lastly in the sun. They are then ground and sifted, the powder the last produced in the mill being of the best quality.

Good madder has a strong smell, somewhat resembling liquorice root. The powder should feel somewhat greasy, and clot together under the fingers, not dry and harsh. The root consists visibly of three parts. The first is an external thin cuticle or skin which is of no use, and is rubbed off along with the adhering dirt by the flail. This shews a thicker bark or cortical part, and within is the woody portion. Both of these are of a high red, but particularly the bark, and both are intermixed with many yellow or fawn coloured particles, which obviously injure the fine red colour, but no means have yet been found of separating them in the root, and they are undistinguishably mixed in the grinding. When the colour is extracted in the dyeing vat the red part is found to be soluble to a much less extent in water than the yellow, and also is less readily extracted, and hence the beauty of the red is injured by long boiling or by using too large a quantity of the root.

Madder in the state used by the dyers is an orange-brown powder, which is very liable to grow damp, and spoil by keeping in a moist place. In addition to what has already been mentioned on the use of this substance in dyeing, (*See Vol. i. p.* 378) the following experiments by Mr. Watt may be mentioned, as giving some information as to its chemical properties.[b]

The best Zealand madder selected for this purpose was of an orange-brown colour, and in moderately fine powder. With water it gave an orange-red infusion, by maceration either with or without heat, but in the latter case the colour was finer. By slow evaporation of the infusion or decoction in a shallow vessel a pellicle gradually forms and sinks to the bottom, and is replaced by others successively. The extract when nearly dry is of a dingy-brown, and is only in part again soluble in water.

Alum added to the infusion gives a precipitate of a very deep brown-red, and the supernatant liquor assumes a brownish-yellow tinge.

The alkaline carbonats added to this supernatant liquor give a blood-red lake, miscible with oils, but far distant from the beauty of the cochineal lake. If an excess of alkali is used the precipitate is redissolved, and the liquor becomes red. Soda does not give so fine a colour as potash. Lime precipitates a dull brown-red lake, without beauty.

The acids added to all madder infusions turn it yellow, but form no precipitate. The natural colour is again restored by alkalies.

Carbonat of magnesia added to the water in which madder is infused turns it of a clear blood-red colour, which, however, when spread upon paper, becomes yellow by the sun's rays.

Different metallic solutions produce the following effects: acetite of lead added to the infusion of madder in water gives a brownish-red precipitate: nitrat of mercury a purple brown: sulphat of iron a beautiful clear brown: and sulphat of manganese also a purplish brown. The solutions of tin, as Berthollet observes, produce a lake void of brilliance or beauty, owing, as this chemist conjectures, to the precipitation of the yellow as well as the red particles of madder, so that this metal which is of so much use in heightening the beauty of cochineal can hardly be used with any advantage for madder.

An improvement in the method of extracting the red of madder for lakes has been published by Sir H. Englefield, for which the gold medal of the Society for the Encouragement of Arts was given to the inventor.[c] It is founded on the discovery that the red colouring part is scarcely soluble in cold water, but in the common method of extraction is chiefly suspended by means of the mucilage of the root. The principal process is the following. Inclose two ounces (troy weight) of the finest Dutch madder, known in commerce by the name of *crop madder*, in a bag capable of containing three or four times that quantity made of strong and fine calico. Put it into a large marble mortar, and pour on it a pint of soft river water, pressing the bag in every direction, and rubbing it as much as may be without danger of bursting. The water will soon become quite opake, and loaded with colouring matter. Pour off the water, and add another fresh pint of water, triturating it with the madder as before, and repeat the operation till the water, the last added, comes off but slightly tinged. About five pints will be required to exhaust the colour, after which the root if taken out and dried will

[b] Berthollet Elem. de Teinture, Vol. ii.

[c] Transact. of the Society, &c. Vol. xxii. p. 141.

be found to have loſt $\frac{1}{16}$ of its weight, and with it its peculiar ſmell, and the colour will be a light nankeen or cinnamon.

The water loaded with the colouring matter muſt then be put into an earthen or well tinned copper veſſel (not iron) and heated till it juſt boils. Then pour it into a large baſon, and add an ounce of alum diſſolved in a pint of hot ſoft water, ſtirring the mixture carefully. Then add about 1½ ounce of a ſaturated ſolution of carbonat of potaſh, which will excite an immediate effervefcence, and a ſubſequent precipitation of a coloured lake. After ſtanding till cold the lake is to be collected, well waſhed with repeated quantities of warm water and gently dried. It will be then found to weigh about half an ounce, or a fourth part of the madder employed.

The above madder lake, which is very beautiful, is found by analyſis to conſiſt of more than 40 per cent. of alumine. The reſt is the colouring matter of the madder.

If the alum ſolution and the madder infuſion, alone without the alkali, be ſuffered to ſtand for a while a dull-red lake will equally precipitate, and the clear liquor will afterwards yield a beautiful ooze-red lake by alkali, but wanting ſufficient body of colour.

A lake equally good with the firſt mentioned, but of a lighter colour, will be afforded by previouſly allowing the madder and cold water to ſtand for a few days in a moderately warm place, whereby a ſlight fermentation will be induced, and a portion of the mucilage of the root deſtroyed. The proceſs is then to be continued as before.

The ſame ingenious experiments alſo ſucceeded very perfectly in obtaining a ſtill more beautiful and equally durable lake, from the freſh madder root imported from Holland, packed up in moſs.

MADREPORSTEIN. Madreporite, *Hauy*.

Its colour is greyiſh-black, or aſh-grey. It occurs in rounded maſſes from twenty to thirty pounds weight. It is compoſed of cylindrical priſmatic diſtinct concretions, either parallel or in diverging bundles. The ſurface of theſe concretions is dull; their croſs fracture preſents a concavity or convexity of a ſhining black, of which the luſtre varies from greaſy to ſilky: the longitudinal fracture is radiated and dull. It is opake, moderately hard, paſſing to ſoft, eaſily frangible. It gives a grey powder.

It diſſolves with effervefcence in nitric acid, and contains, according to an analyſis by M. Schroll,

63	Carbonated lime
10	Alumine
13	Silex
11	Oxyd of iron
97	
3	loſs
100	

This mineral was found by the Baron Moll in the valley of Rüſbach, in Saltzburg, in detached maſſes. It ſeems nearly akin to the moſt recent ſecondary limeſtone. Its name is derived from the reſemblance in the diſpoſition of the priſms of which it is compoſed to thoſe of certain lithophytes. Some naturaliſts have ſuppoſed it to be a real petrifaction, but apparently without much reaſon, as its intrenal ſtructure is wholly different from that of the acknowledged petrifactions of this claſs.

MAGISTERY. This term appears to have been formerly nearly ſynonimous with *Precipitate*, but it is now almoſt diſuſed, except in one or two combinations, ſuch as

Magiſtery of Biſmuth, which is the white oxyd of this metal precipitated from the nitrous ſolution by the addition of water.

Magiſtery of Sulphur, which is ſulphur precipitated from its alkaline ſolution by an acid.

MAGNESIA NIGRA or MANGANESE, which ſee.

MAGNESIA ALBA, the earth *Magneſia*. *Magneſie* Fr. *Bitterſalzerde*, Germ.

This earth is procured pure, either by adding potaſh or ſoda to any acid ſolution of magneſia, or, more readily, by calcining the dry carbonat of magneſia in a full red heat for about half an hour till it gives no effervefcence with acids.

The method of procuring the *Carbonat of Magneſia* has been deſcribed under that article. The common carbonat loſes by complete calcination about 55 per cent. of its weight, of which about 34 parts are carbonic acid and 21 are water. It ſhrinks by the proceſs to a very ſmall part of its original bulk.

Pure magneſia is a light earth of a pure and perfect whiteneſs, and abſolutely inſipid, though as commonly prepared it contains a ſmall portion of lime, to which it owes the ſlightly acrid taſte which it poſſeſſes. It does not give out any heat with water, as lime does, nor is it ſenſibly diſſolved therein. When expoſed to the air it does not *ſlack* or regain the carbonic acid which it had loſt by calcination, in which reſpect alſo it remarkably differs from lime. It

readily changes the blue of violets to green, as the alkalies do, and hence magnesia has been reckoned to be one of the alkaline earths. When strongly heated it becomes phosphorescent.

Magnesia readily unites with sulphur, but more feebly than the other alkaline earths. This combination, when dissolved in water, forms a yellow liquor the *hydrosulphuret of magnesia*. (See the Article *Sulphuret*.)

All the acids dissolve magnesia, forming salts mostly very bitter and deliquescent, and very soluble in water. The fixed alkalies decompose these salts totally, but ammonia only partially separates the earth, forming with the remainder a triple soluble salt composed of ammonia, magnesia, and the acid which held it in solution.

The separation of magnesia from alumine in chemical analysis is attended with some peculiar difficulties, described under the article *Alumine*. They appear to depend on a strong affinity between these earths, which modifies and alters the usual modes in which they are acted on by the different chemical agents when separate.

Magnesia is perfectly infusible by itself, the heat even of oxygen gas from the blow-pipe only producing a slight induration. In earthy compounds magnesia appears to have very little effect in promoting fusion as the other alkaline earths have, but rather the contrary, so that the magnesian earths are found a valuable ingredient in the composition of the finest porcelain, which will bear a most intense heat without actual fusion.

The combinations of magnesia with the different acids will be found under the respective acids.

The affinities of magnesia are in the following order, the oxalic, phosphoric, sulphuric, fluoric, arsenic, nitric, muriatic, tartaric, citric, lactic, benzoic, acetic, boracic, sulphureous, carbonic, and prussic acids.

MAGNESIA NATIVE. Naturliche Talkerde, *Wern*. Magnesie native, *Broch*.

Its colour is yellowish-grey, with spots and dendritic delineations of blackish-brown. It occurs in mass, tuberous or carious. Internally it is dull. Its fracture in the great is rather large and flat conchoidal, in the small it is splintery. Its fragments are indeterminate sharp-edged. It is opake, soft, and easy frangible. It is somewhat unctuous to the touch, adheres a little to the tongue, and is moderately heavy.

According to an analysis by Dr. Mitchel and Prof. Lampadius it consists of,

51	Carbonic acid
47.4	Magnesia
	A trace of iron

It has hitherto been found only at Raubschütz in Moravia, where it occurs in serpentine, accompanied by Meerschaum.

MAGNESIA OPALINA is a preparation of ANTIMONY. (See this Article, p. 87.)

MAGNESIA VITRIOLATA. See SULPHAT of *Magnesia*.

MALACHITE. See COPPER (Ores of.)

MALACOLITE. Malacolith, *Wern*. Sahlite, *D'Andrada*.

Its colour is greyish-green, passing to pale leek green. It occurs in mass; also crystallized in six-sided prisms, with truncatures on two opposite edges. It is slightly glistening with a waxy lustre. Its longitudinal fracture is lamellar in three directions. It is translucent on the edges, scratches glass with difficulty, and is very soft to the touch, (whence its name.) Sp. gr. 3.23.

Before the blow-pipe, according to Lelièvre, it is fusible into a spungy glass, but according to D'Andrada, it is infusible. It has been analysed by Vauquelin, and appears to contain

53	Silex
20	Lime
19	Magnesia
3	Alumine
4	Oxyds of iron and manganese
99.	

This mineral was first met with in Sweden, in the silver-mines of Sahla in Westermanland; it has since been found at Buoen, near Auen in Norway. There appears to be a strong analogy in many respects between malacolite and augite.

MALIC ACID, or *Acid of Apples*. Apfelsaure, *Germ*.

This acid was first discovered by Scheele, in the juice of unripe apples, who gave it thence the name of *Malic Acid* or *Acid of Apples*. In this fruit it is mixed with mucilage and many other substances, from which it is separable by the following method indicated by this illustrious chemist. Bruise the fruit in a mortar and squeeze out the juice; strain it through a cloth, saturate it with potash, and pour into the liquor a solution of acetited lead. A white insoluble salt, the malat of lead, falls down which must

be collected and washed with cold water. Then add to it sufficient dilute sulphuric acid, to displace the malic from the oxyd of lead; insoluble sulphat of lead will be left at the bottom, and the supernatant liquor will be the pure malic acid in a liquid state, which is the only state in which it can be exhibited, as it is uncrystallizable, and cannot be evaporated to dryness without decomposition. The precise quantity of sulphuric acid necessary to be added may be ascertained in the following manner: continue to pour in this acid by degrees, and with frequent stirring, till the liquor loses the sweet taste of lead, and is purely acid: and on the other hand to detect any excess of sulphuric acid add a few drops of acetited lead to a drop or two of the liquid, which will form a precipitate in any case, but if sulphuric acid be present the precipitate will not redissolve in dilute nitric acid, though it will easily dissolve if only malic acid be contained in it.

Malic acid has also been found by Vauquelin to be abundantly contained in the native juices of several succulent vegetables, partly uncombined, but chiefly united with lime, and the malat of lime is held in solution by an excess of its own acid, this calcareous salt being readily soluble in most acids that do not decompose it, though without this, it remains but little soluble in water.

The indications by which this salt is detected in vegetable juices are so accurately given by Vauquelin that we shall here insert them.[a] These juices are always sensibly acidulous so as to redden litmus paper: they give a copious precipitate by the carbonated or pure alkalies, and by oxalat of ammonia: sulphuric acid when added forms an immediate deposit of sulphat of lime: lime-water also gives a precipitate, by neutralizing the excess of malic acid; hence not only the newly formed malat of lime is deposited, but also the portion which in the natural juice was held in solution by excess of acid: lastly acetited lead gives an abundant light flocculent precipitate, which is easily redissolved by acetous acid. This solubility of the malat of lead, in a weak acid, so much exceeds that of the sulphat, or even muriat of this metal (which are, rigorously speaking, somewhat soluble in acetous acid) that this test will easily distinguish the malic salt. There is more difficulty in drawing any satisfactory inference from it when certain other vegetable acids are present, such as the citric, tartareous, and oxalic acids, all of which, as well as the malic acid, form a copious precipitate with acetite of lead, which precipitate is again soluble by any weak acid, nor does there appear any very satisfactory way of immediately deciding which of these vegetable acids is present, except that the malat of lead is much more readily soluble, and besides is light and flocculent, whereas the other salts of this metal are heavy, and curdled in appearance. When each acid is left naked after decomposition of the saturnine salt by sulphuric acid, the malic acid is then distinguishable from the above-mentioned vegetable acids by remaining entirely uncrystallizable.

Another useful test of the presence of malat of lime in native vegetable juices, is furnished by the addition of alcohol, which, when this salt is present, separates it in the form of a white homogeneous soft magma, resembling a thick soup. When these juices are evaporated to dryness, they leave a yellow glossy matter like gum arabic, which affords a large quantity of carbonat of lime by incineration.

The malic acid is often found mixed with other acids, particularly the citric, in the sour juices of fruits. To separate them, Scheele evaporates the juice to the consistence of honey, and adds alcohol, which dissolves the two acids, and leaves a great quantity of gummy mucilage. The alcoholic solution is then evaporated to drive off the spirit, and the remaining liquor nearly saturated with chalk, which forms both a malat and a citrat of lime, the latter of which by further evaporation is almost entirely deposited, whilst the former remains mostly in the clear liquor. The liquor is then mixed with alcohol (which will not take up the malat of lime, though it dissolves the pure acid), whereby the calcareous malat is separated in the state of a white flocculent mass from a sugary matter, which the alcohol dissolves; and the malat of lime, now pure, is decomposed by acetited lead, and malat of lead is produced, whence the malic acid is obtained separate by means of the dilute sulphuric in the way already mentioned.

The malic acid, besides being found native, is also produced during the action of nitric acid on sugar, in the way described under the article Oxalic Acid, which latter also is obtained in the process. The oxalic acid is crystallizable, and may be thus mostly separated. The liquid residue is malic acid mixed with any nitric acid which may have escaped decomposition. A further treatment with fresh nitric acid produces a fresh crop of crystals of oxalic acid, whence it is probable that the malic acid is the

[a] An. de Chin. tom. xxxiv. & xxxv.

first product of sugar when acted on by nitric acid, and differs from the oxalic either in being less oxygenated, or perhaps from being combined with a quantity of sugar yet unaltered, to which its uncrystallizable nature may be owing.

The malic acid, in this case, may be separated with tolerable accuracy from the oxalic and nitric in the following way: add lime-water as long as any precipitate takes place, which will be chiefly oxalat of lime, and thus nearly all the oxalic acid will be separated: then saturate the clear liquor with chalk, which will therefore produce the nitrat and malat of lime: add alcohol, which will dissolve the nitrat of lime and a saccharine matter existing in the liquor, and the malat of lime remaining may then be further treated with acetited lead and sulphuric acid, as above described.

Or if the mother-liquor remaining after the oxalic acid has first been separated by crystallization be exposed to a moderate frost, the watery part alone will congeal, after which an intense artificial cold of about 7° will cause the malic acid to crystallize,[a] and these crystals being picked out and set to drain will soon again liquefy as the temperature rises, and the liquor will be malic acid in very great purity.

The pure malic acid has been but little examined. It is uncrystallizable except in intense cold as just mentioned, but when slowly dried it forms a sort of glutinous varnish on the vessel that contains it. It cannot be kept for any length of time, as it soon ferments, and new products, chiefly acetous and carbonic acids, are generated.

The combinations of this acid with the alkaline earthy and metallic bases, or the *malats*, have been scarcely examined, except the malats of lime, and of lead, which are so nearly concerned in the extraction and analysis of this acid. Of the properties of these salts nothing more need be added to what has been already mentioned. The malic acid precipitates the nitrats of mercury, lead, and silver,[b] in which it differs from the citric acid. The malic acid forms with magnesia a very deliquescent salt readily soluble in alcohol, whereas with alumine it gives a salt almost insoluble in water or alcohol, and Mr. Chenevix has therefore suggested the use of this acid to perform the very difficult operation of separating these two earths. (See ALUMINE.)

The malic acid is not applied to any use.

MALTHA. See BITUMEN.

MANDELSTEIN. See TRAP.

MANGANESE. *Manganèse*, Fr. *Braunstein*, Germ. *Manganesium. Magnesia nigra.*

Manganese is a metal of an iron-grey colour, brittle, and easily oxydable on exposure to the air. When in the state of black oxyd it communicates to borax a red tinge, which is destroyed by the internal blue flame of the blowpipe, but is restored by the external flame or the addition of nitre.

§. 1. *Ores of Manganese.*[a]

Sp. 1. Grey Manganese.

Of this there are reckoned the four following subspecies.

1. *Subsp.* Radiated grey manganese. *Strahliges grau braunsteinerz*, Wern. *Manganese gris rayonné*, Broch.

Its colour is steel-grey passing to iron-black. It occurs in mass, disseminated, or crystallized in rhomboidal prisms, the alternate angles of which are about 100° and 80°, which prisms are again divisible in the direction of the short diagonal of the bases. Sometimes the prism is terminated by dihedral or tetrahedral summits, or the sides of the prism itself are truncated or bevilled.

This mineral also occurs in the form of acicular crystals, either diverging, radiated, or interlaced. The surface of the crystals is longitudinally streaked and bright shining. Internally it is glistening or shining with a metallic lustre. Its fracture is strait and usually fine striated, more or less divergent. Its fragments are wedge-shaped and splintery. It occurs in lengthened coarse granular distinct concretions. Its streak is black and dull. It marks strongly when rubbed; is soft, brittle, and easily frangible. Sp. gr. 3.7 to 4.7.

A specimen of this mineral in large rhomboidal prisms, from Ilefield in the Hartz, was analyzed by Klaproth,[b] and afforded

90.5	Brown oxyd of manganese
2.25	Oxygen gas
7.	Water
99.75	
.25	Loss
100.00	

Another specimen from Moravia in short diverging acicular crystals gave

89.	Brown oxyd of manganese
10.25	Oxygen gas
0.5	Water
99.75	

[a] Orig. Communic. [b] Fourcroy. [a] Emmerling, Hauy, Brochant, Kirwan, Jameson. [b] Analyt. Ess. II. p. 243.

It occurs in veins in porphyry accompanied by heavy ſpar, calcareous ſpar, and iron ochre.

It is found in England in the counties of Cornwall, Devon, Somerſet, and Derby; in Aberdeenſhire, in Scotland; in Saxony, Bohemia, Moravia, and Sileſia, in Germany; in Switzerland, the North of Italy, and France.

2. *Subſp.* Foliated grey manganeſe. *Blättriges grau braunſteinerz*, Wern. *Manganeſe gris lamelleux*, Broch.

Its colour is the ſame as the preceding. It occurs in maſs, diſſeminated, or cryſtallized in rectangular tables, which are often very ſmall, and difficultly determinable. Its fracture is foliated and delicately ſtreaked. It is more eaſily frangible than the preceding ſubſpecies, of which however it ſeems to be merely a variety. It occurs in Devonſhire, at Ilefield in the Hartz, Saxony, Bohemia, &c.

3. *Subſp.* Compact grey manganeſe. *Dichter grau braunſteinerz*, Wern. *Manganeſe gris compacté*, Broch.

Its colour is ſteel-grey paſſing into iron-black. It occurs in maſs, diſſeminated, in angular fragments, botryoidal, reniform, carious, ſtalactitic, or tubercular. Its external luſtre is eaſual; internally it is gliſtening, metallic: its fracture is even, flat-conchoidal, or fine-grained uneven. Its fragments are indeterminate blunt-edged. It ſometimes preſents thick curved lamellar diſtinct concretions. It varies conſiderably in hardneſs, and equally ſo in its ſtreak, that of the harder varieties having a metallic luſtre, but that of the others being dull. It is brittle and eaſily frangible. Sp. gr. 3.7 to 4.1.

The manganeſe of Romanèche in France, firſt deſcribed by Dolomieu, belongs to this ſubſpecies; it is hard enough to ſcratch glaſs and give fire with ſteel. According to an analyſis by Vauquelin it contains

50.	Yellow oxyd of manganeſe.
33.7	Additional oxygen.
14.7	Barytes.
1.2	Silex.
0.4	Carbon.
100.0	

It is the opinion of the able chemiſt who performed this analyſis that the barytes is chemically combined with the metallic oxyd in this ore.

4. *Subſp.* Earthy grey manganeſe. *Erdiges grau braunſteinerz*, Wern. *Manganeſe gris terreux*, Broch.

Its colour varies between ſteel-grey and browniſh-black. It occurs in maſs or diſſeminated, or ſuperficial, or dendritic; it is ſometimes dull, ſometimes glimmering, with a metallic luſtre.

Its fracture when dull, or nearly ſo, is fine-grained earthy, but that of the other varieties is fine ſcaly. It ſoils ſtrongly; is very tender, ſometimes even friable; is ſomewhat meagre to the touch. Sp. gr. 2 to 3.

The gas that it yields by ignition is almoſt wholly carbonic acid.

According to an analyſis by Klaproth it contains

68.	Brown oxyd of manganeſe.
6.5	Oxyd of iron.
1.	Carbon.
1.	Barytes.
8.	Silex.
17.5	Water.
102.0	

It occurs in Cornwall and Somerſetſhire in England; Ilmenau in Saxony; Perigueux in France, &c.

The *black wad* of Derbyſhire and Devonſhire appears to be a variety of this ſubſpecies. It poſſeſſes the ſtriking property of inflaming ſpontaneouſly when mixed with one fourth of its weight of linſeed oil and ſet in a dry warm place. According to an analyſis of this ſubſtance by Mr. Wedgwood it conſiſts of the oxyds of iron and manganeſe in nearly equal parts.

Sp. 2. Black manganeſe. *Schwarz braunſteinerz*, Wern. *Manganéſe noir*, Broch.

Its colour is between browniſh-black and dark greyiſh-black. It occurs in maſs, diſſeminated, or in very ſmall ſomewhat lengthened pyramidal octohedrons, grouped together in rows. The ſurface of the cryſtals is more or leſs ſhining; internally it has a ſlight vitreous luſtre. Its fracture is imperfectly and curved lamellar. Its ſtreak is dull, and of a reddiſh-brown; it is tender, brittle, and eaſily frangible.

It is a rare mineral, and uſually accompanies grey antimony. It has not been analyzed.

It is found at Ehrenſtoch, near Ilmenau, in Saxony; at Rabenſtein, in Bavaria; Führbach, in Salzburg; and Gora, in Weſt Gallitſia.

* Journal des Mines, No. xix. p. 27.

Sp. 3. White manganeſe.

Its colour is ſnow-white, yellowiſh or reddiſh white. It occurs in maſs, diſſeminated, mamillated, or in imperfect flattened rhomboids, or lenticular cryſtals. Internally it is ſlightly gliſtening, with a luſtre between reſinous and vitreous; it is tranſlucent at the edges; its fracture is curved foliated. It is moderately hard. Sp. gr. 2.79.

It effervesces with the mineral acids, and with the muriatic gives a ſmell of oxymuriatic acid; by ignition it becomes black, and then ſcarcely effervesces with nitrous acid.

According to Kirwan it contains 37 per cent. of air, the chief of which is carbonic acid.

From an analyſis by Lampadius it conſiſts of

48.	Oxyd of manganeſe.
2.1	Oxyd of iron.
49.2	Carbonic acid.
0.9	Silex.
100.2	

This ſubſtance appears to have a ſtrong analogy with pearl ſpar.

Sp. 4. Red manganeſe. *Roth braunſtienerz*, Wern. *Manganeſe rouge*, Broch.

Its colour is light roſe-red, which by decompoſition becomes light yellowiſh-brown. It occurs in maſs and diſſeminated. Internally it is dull; its fracture is even, paſſing into flat conchoidal. Its fragments are indeterminately angular ſharp-edged. It is ſlightly tranſlucent; is hard, brittle, and eaſily frangible. Sp. gr. 3.23.

By ignition it becomes reddiſh-brown, and is infuſible before the blowpipe without addition: in a ſtream of oxygen gas it melts eaſily into a dark brown tranſlucent bead, attractable by the magnet. It ſlightly effervesces with nitrous and muriatic acids. According to an analyſis by Ruprecht it conſiſts of

35.17	Oxyd of manganeſe.
7.14	Oxyd of iron.
55.06	Silex.
1,56	Alumine.
0.78	Water.
99.71	

It occurs at Kapnick, Offenbanya, and Nagyag, in Tranſilvania, where it ſerves as the matrix for the gold ores that are wrought at thoſe places. It was ſuppoſed by Born and other mineralogiſts to be a variety of felſpar.

Sp. 5. Sulphuret of manganeſe.[d] *Black blende* of Müller de Reichenſtein.

Its colour is between browniſh-black and iron-black: it occurs maſſive and diſſeminated: it is ſhining with a metallic luſtre. Its fracture is fine-grained uneven, paſſing into obſcurely foliated: its fragments are indeterminately angular. It is opake. It gives a dull greeniſh braſs-yellow ſtreak; it is moderately hard and eaſily frangible. Sp. gr. 3.95.

When pulverized it gives out ſulphuretted hydrogen on the addition of nitrous acid.

It has been analyzed by Klaproth, and conſiſts of

82.	Oxyd of manganeſe.
11.	Sulphur.
5.	Carbonic acid.
98.	

It occurs in veins at Szekeremb in Tranſilvania, together with the preceding ſpecies, and ſerves as a matrix for the ores of gold and tellurium.

Sp. 6. Phoſphat of manganeſe and iron.[e]

Of this mineral only the few following particulars have as yet been publiſhed.

Its colour is reddiſh-brown: its fracture is lamellar; it poſſeſſes a brilliant and ſomewhat chatoyant luſtre; when divided into thin lamellæ it is ſemitranſparent; its hardneſs is a little greater than that of glaſs, it gives a greyiſh-yellow ſtreak. Sp. gr. 3.65.

It is readily fuſible before the blowpipe into a black enamel.

According to an analyſis by Vauquelin it is compoſed of

42.	Oxyd of manganeſe.
31.	Oxyd of iron.
27.	Phoſphoric acid.
100.	

It has hitherto been found only in the vicinity of Limoges, in France, where it was at firſt miſtaken for an ore of tin.

§ 2. *Aſſay and analyſis of ores.*

The analyſis of the ores of manganeſe, though upon the whole ſufficiently ſimple, is ſubject to ſome difficulties and ambiguities, in conſequence of which chemiſts are by no means agreed, either upon the beſt mode of proceeding or upon the reſults. The ſteps in the method of analyſis that require the moſt care are thoſe

[d] Klapr. Analyt. Eſſ. II. p. 26.

[e] Ann. de Chem. tom. xli. p. 242.

that relate to the separation of the oxyds of iron and manganese, and to the ascertainment of the amount and purity of that portion of oxygen which is so loosely combined with the manganese as to be capable of being separated by mere heat, or the action of muriatic acid.

We have already in the article Iron given some account of the methods pursued by the ablest chemists, in separating the mixed oxyds of iron and manganese, but as this is a nice matter, we shall take the liberty of recapitulating what we have before stated, and of making some additional observations.

1. The method proposed and practised by Bergman[f] is the following. Having previously separated the earthy and other ingredients, let the residue, consisting of the mixed oxyds of the two metals, be digested in nitric acid and boiled to dryness, in order to oxygenate completely both the iron and manganese; let some dilute nitric acid and a little sugar be then added, and by cold digestion for a few hours the manganese will have dissolved, forming a limpid nearly colourless fluid, while the greatest part of the oxyd of iron will remain untouched. Let the nitrat of manganese thus formed be decomposed by a carbonated alkali, and the precipitate, after washing, be ignited for half an hour; then let the cold digestion in dilute nitric acid and sugar be again repeated, and the oxyd of iron, with the exception of a few atoms, will remain untouched, while the manganese is dissolved. To this last solution, moderately diluted, add drop by drop some caustic ammonia till the commencement of precipitation; then boil the whole for a minute, after which the whole of the iron may be separated by the filter or decantation, the manganese remaining in solution.

2. A somewhat different method was followed by Cordier and Beaunier, in their analyses of several specimens of French manganese.[g] Having completely oxydated by means of nitric acid the iron and manganese, the mixed oxyds were digested for some hours in repeated portions of boiling distilled vinegar; the insoluble residue consisted of oxyd of iron holding a small quantity of manganese, the rest of the manganese (with probably a little iron) being taken up by the vinegar. This method however is more tedious, and apparently less accurate, than that adopted by Bergman. The following improvement upon it, first suggested by M. Porcell, has since been employed with success by Vauquelin. The mixed oxyds, after being dissolved in muriatic acid and precipitated by a mild alkali, are to be dissolved in distilled vinegar and the whole evaporated very nearly to dryness; from this residue a fresh portion of acetous acid will take up the whole of the manganese, and a little of the iron. This second solution being again evaporated to dryness, and treated afresh with acetous acid, will deposit the greatest part of its iron; and thus by repeating the process two or three times the whole of the iron may be separated with great accuracy. When nothing but manganese remains in solution the liquor will be entirely colourless, and will give a white precipitate with prussiat of potash.

3. Mr. Kirwan[h] proposes to separate the two oxyds by boiling them in a strong solution of caustic fixed alkali, which he says will take up the manganese and leave the iron. This however appears to be an oversight: for although oxyd of manganese is soluble in alkali in the *dry* way, a solution of the same has no solvent action whatever upon it; and, in consequence, this very process is used by Klaproth to separate alumine from manganese, the former alone of these substances being capable of being taken up by this fluid.

4. According to Richter[i] manganese and iron may be separated from each other by dissolving the mixture in sulphuric acid, and then adding a concentrated solution of tartrite of potash, both liquors being warm: by evaporating the whole gently till the sulphat of potash begins to form, the tartrite of manganese will be entirely deposited in a pulverulent state while the iron will remain dissolved. Klaproth however found this method ineffectual when muriatic acid was employed instead of sulphuric.[k]

5. The solubility of prussiat of manganese in a dilute acid, and even in pure water, and the insolubility of prussiat of iron in the same menstrua, affords an accurate and satisfactory method of separating these two metals from each other. To the compound muriatic solution, containing a slight excess of acid, add prussiat of potash till a white precipitate makes its appearance; then digest the whole for some time in a moderate heat, and by decantation or the filter separate the blue precipitate from the supernatant liquor; the whole of the iron will be found in the regenerated Prussian blue, and the manganese will remain in solution, from which it may be procured by means of a carbonated alkali.

[f] Opuscula II. p. 234. [g] Journ. des Mines, No. lviii. p. 769. [h] Mineralog. II p. 387. [i] Ditto, p. 461. [k] Analyt. Ess. II. p. 108.

6. There is yet another method of feparating iron and manganefe, which has obtained the fanction of many able chemifts, and when performed with care is capable of much accuracy. Having previoufly diffolved the mixed oxyds in fulphuric or muriatic acid, and diluted the folution to a confiderable degree, add, drop by drop, fome carbonated alkali, till the liquor begins to be permanently turbid; then boil it for a few minutes and feparate by the filter the brown oxyd of iron which will have been precipitated: into the clear liquor add as before a few drops of carbonated alkali till what falls down is of a pure white colour, then boil the whole and feparate this fecond precipitate in the fame manner as the firft. By this mode three diftinct portions will be obtained, of which the firft precipitate is pure oxyd of iron, the fecond is a mixture of iron and manganefe with the latter confiderably in excefs, and the folution is muriat of manganefe entirely free from iron. The fecond precipitate being rediffolved in muriatic acid and treated with carbonated alkali, as already mentioned, will be feparated into oxyd of iron and muriat of manganefe with fo much accuracy as to render it unneceffary to carry on the procefs further.

7. The laft method which we fhall mention, and which at the fame time is the moft recently difcovered, the moft accurate, and the moft expeditious, though not fo economical as fome of the former, is by means of fuccinat of foda or ammonia. It is thus effected.[1] Diffolve the mixed oxyds in muriatic acid, and then by means of a cauftic alkali bring the folution to a ftate of perfect faturation; after this drop in fuccinat of foda or ammonia as long as a precipitation takes place; feparate by the filter the fuccinated iron from the clear liquor and edulcorate it by repeated ablutions of cold water: add together the wafhings and clear liquor and decompofe the whole by cauftic foda, a precipitate will fall down, which when wafhed and dried is pure oxyd of manganefe.

Having thus ftated the principal means of overcoming one of the difficulties in the analyfis of manganefian ores, we proceed to fay a few words on the method of afcertaining the amount and purity of the loofely combined oxygen. It is to be regretted however that this (which in an economical point of view is a matter of chief importance) fhould hitherto have received fo little notice. The moft obvious method of proceeding is by dry diftillation at a red heat, in which both the gas and moifture will be driven off, and may be collected and examined by the ufual reagents. This, however, is liable to fome objections, and principally the two following. In the firft place, it only fhews the quantity of oxygen *gas* that may be procured from the manganefe fo examined; but as the principal employment of this metallic oxyd is in the bleacheries, where it is ufed for making oxymuriatic acid, it would be eminently ferviceable fo to ftate the refults of an analyfis as to enable the manufacturers to compare different fpecimens of manganefe with a view to their commercial value. For this purpofe the oxyd of manganefe muft be decompofed, not into the brown oxyd and oxygen, but into the white oxyd and oxygen: mere heat however is not capable of feparating more than that portion of oxygen which conftitutes the difference between the brown and the black oxyds, whence it happens that many famples, which yield little or no oxygen by fimple ignition, may yet be employed to good purpofe in the preparation of oxymuriatic acid.

The fecond objection is that the fource of the carbonic acid which is commonly mixed with the oxygen thus procured, is often extremely ambiguous. The manganefian ores frequently contain both carbon and carbonat of lime; but by a red heat not only part of the acid from the carbonat is driven off, but a portion of the oxygen of the manganefe, as it is difengaged, combines with the carbon, and thus alfo forms carbonic acid.

Some chemifts, particularly Vauquelin and his pupils, in their analyfes of the ores of manganefe, confider the native oxyd as compofed of the white oxyd, and a greater or lefs quantity of oxygen, but unfortunately adopt the very erroneous method of eftimating this excefs of oxygen merely by the lofs that appears at the end of the analyfis, whence its apparent amount is greater the more carelefsly the analyfis has been performed.

The fubftances that the commoner ores of manganefe have hitherto been formed to be compofed of, are the oxyds of manganefe and iron, filex, barytes, alumine, carbonat of lime, carbon, and water. It is not improbable, that all thefe may coexift in the fame fpecimen, in which cafe the following would probably be the beft method of performing its analyfis.

Take 400 grains previoufly reduced to a fine

[1] Analyt. Eff. II. p. 108.

powder, and dried at 212° Fahr. divide the whole into two equal parts, and treat the firſt 200 grains in the following manner.

(*a*) Put the ore into a ſmall retort, and pour upon it about twice its weight of moderately dilute and colourleſs nitric acid; the *carbonic acid* of the carbonat of lime will be thus diſengaged without the application of heat, and may be received in an inverted jar of lime-water; from the regenerated carbonat thus produced, its acid may be calculated according to the known proportions. When the evolution of carbonic acid ceaſes, transfer the contents of the retort into a digeſting flaſk, add a ſmall piece of ſugar, and apply a gentle heat; when the action of the acid has ceaſed, pour off the clear fluid, and digeſt the remainder with freſh nitric acid and ſugar as long as any thing ceaſes to be taken up; then mix together the nitric ſolutions and the waſhings of the undiſſolved reſidue.

(*b*) The reſidue juſt mentioned being dried at a heat below ignition and weighed, muſt be ignited in an open crucible to burn off the *carbon*, the amount of which will be indicated with ſufficient exactneſs by the difference of weight before and after ignition.

(*c*) The reſidue of *b* is to be boiled to dryneſs in a ſilver crucible with thrice its weight of liquid cauſtic ſoda; the hardened maſs is to be diſſolved in dilute muriatic acid, then evaporated nearly to dryneſs, and boiled with water; a fine white powder will remain undiſſolved, which is *ſilex*.

(*d*) Add together the nitric (*a*) and muriatic (*c*) ſolutions, and pour in liquid ammonia as long as any precipitation takes place; ſeparate the precipitate by filtration, and add the waſhings to the clear liquor.

(*e*) To the clear liquor of *d* pour in a ſlight exceſs of ſulphuric acid, and make the whole boiling hot; the precipitate being ſpeedily ſeparated by the filter and waſhed, is ſulphat of *barytes*.

(*f*) Evaporate the clear liquor of *e* to a very ſmall bulk, and mix it with cold alcohol; the reſulting precipitate is ſulphat of *lime*.

(*g*) The precipitate of *d* is now to be digeſted in cauſtic ſoda: when the action of the alkali ceaſes, pour off the liquor, edulcorate the reſidue, add the waſhings to the liquor, neutralize with muriatic acid, and then pour in carbonat of ammonia, till no further precipitation takes place. The precipitate being waſhed and ignited is *Alumine*.

(*h*) The reſidue of *g* which is inſoluble in ſoda, conſiſts of the mixed oxyds of manganeſe and iron, which may be ſeparated by any of the methods already mentioned. If that deſcribed in paragraph 6 is preferred, muriatic acid is to be added till the whole of the oxyd is taken up and then carbonated ſoda will throw down a precipitate which when ignited is pure *oxyd of iron*.

(*i*) To the muriatic ſolution of *h* add cauſtic ſoda; the precipitate thus occaſioned when waſhed and ignited in an open crucible is *brown oxyd of manganeſe*.

The component parts of the ore are now all aſcertained except the water and looſe oxygen, and in order to determine theſe we muſt have recourſe to the ſecond portion of the ore, weighing like the firſt 200 grains.

(*a*) Put the ore into a ſmall glaſs retort connected with a pneumatic mercurial apparatus, and make the bulb of the retort moderately red hot as long as any gas is diſengaged. By this means the *water* will be condenſed in the receiver, and the gas will paſs forwards into the inverted jar.

(*b*) The air thus collected being mixed with nitrous ſulphat of iron, the amount of its *oxygen* is readily aſcertained. The weight of the oxygen added to that of the brown oxyd of manganeſe gives very nearly though ſomewhat leſs than the entire weight of the manganeſe in the ſtate in which it exiſts in the ore. The *diſpoſable* oxygen, or that which may be applied to the preparation of oxymuriatic acid, is found by deducting 6 per cent. from the brown oxyd, and adding this to the weight of the gaſeous oxygen. Of the diſpoſable oxygen, 16 parts repreſent 100 of oxymuriatic acid, produced by diſtilling together the ore and common muriatic acid.

We ſhall conclude this ſection by ſtating the particulars of ſome of the moſt intereſting analyſes that have yet been publiſhed of the ores of manganeſe.

Radiated grey Manganeſe.

A cryſtallized ſpecimen of this mineral was thus analyſed by Klaproth.[m] 200 grains being pulverized were digeſted in the cold with muriatic acid; in a few hours the whole diſſolved without effervefcence, forming a deep brownred fluid. Being then heated a copious extrication of oxymuriatic acid gas took place; when this had ceaſed, and the liquor was diluted with water it exhibited a faint reddiſh colour, a few atoms of carbon being the only

[m] Analyt. Eſſ. II. p. 243.

part of the ore remaining undissolved. The solution was divided into two equal parts, one of which was examined with the following reagents.

Sulphuric acid produced no precipitate; therefore no barytes was present.

Prussiat of potash threw down a peach-coloured precipitate, therefore scarcely any iron was present.

Carbonated alkalies occasioned a white precipitate, which retained its colour on exposure to the air.

Caustic alkalies gave a brown precipitate.

Water impregnated with sulphuretted hydrogen produced no turbidness or other change.

The other half of the solution was neutralized with carbonat of potash till a slight turbidness appeared; and being then boiled and filtered, a few scarcely perceivable brown particles of oxyd of iron were separated. To the remaining fluid, carbonat of potash was added to full saturation at a boiling temperature; 136 grains of carbonated manganese was thus obtained, which (after strong ignition) weighed 88.5 grains. This oxyd being then heated with strong nitric acid and sugar entirely dissolved, forming a colourless fluid, from which, by distillation to perfect dryness, a lead-grey mass of perfect oxyd of manganese with a metallic lustre was procured.

200 grains more of the ore were heated thoroughly red in a glass retort connected with a pneumatic apparatus, by which means 14 grs. of water and 4.5 grs. of oxygen gas were collected, the remainder in the retort weighing 181 grs.

Hence 100 parts of the ore contain

90.5	Brown oxyd of manganese.
2.25	Oxygen.
7.	Water.
99.75	

Compact grey manganese of Romaneche.

This was analyzed by Vauquelin[a] in the following manner:

100 parts being treated by muriatic acid there remained 1.6 of a black matter; this residue on exposure to the air inflamed, and left behind 1.2 of silex.

Sulphuric acid being added to the solution threw down 21 of sulphated barytes, equivalent to 14. of barytes. From the remaining liquor carbonat of potash precipitated 96. of very white carbonat of manganese, which by strong distillation in an earthen retort afforded 48 of a greenish-grey oxyd of manganese.

Thus there have been obtained

48.	Oxyd of manganese.
14.	Barytes.
1.2	Silex.
0.4	Carbon.
63.6	

The 36.4 parts requisite to make up the original 100 is considered by Vauquelin as oxygen abstracted from the ore by its solution in muriatic acid and the subsequent production of oxymuriatic acid. To this estimate however it may be objected, that no notice whatever is taken of the water which probably existed in the ore, that no allowance is made for the loss experienced in almost every analysis, and that it is contrary to Bergman's experiment which has never yet been disputed, in which from 100 of metallic manganese he procured by solution in nitric acid and precipitation by caustic alkali 168 of black oxyd, according to which 48 parts even of metallic manganese can only take up 32 of oxygen.

Sulphuret of manganese.

Klaproth's analysis of this mineral is as follows:[a] 100 grains were heated red hot in a retort connected with a mercurial pneumatic apparatus, by which 5 grains of carbonic acid and a scarcely perceptible quantity of moisture were obtained. Another 100 grains were treated with moderately strong nitric acid; sulphuretted hydrogen gas immediately escaped with a copious effervescence, and the ore was dissolved with the exception of 5.5 grs. which were sulphur. The filtered solution being diluted was divided into two equal parts of which one was decomposed by caustic soda; a white precipitate fell down which speedily became brown by exposure to air; the other half was decomposed by carbonated soda, and the white precipitate hence resulting remained unaltered in colour by drying; hence it contained no iron.

Another 100 grains was treated in the cold with dilute nitric acid; 34 grs. of sulphuretted hydrogen escaped, and one grain of sulphur remained floating in the solution. Carbonat of soda being added to the filtered solution, a white carbonated oxyd of manganese fell down, weighing 145 grs. which by ignition in a small glass retort was reduced to 82 grs. the colour remaining unaltered. To this residue half its weight of sulphur (i. e. 41 grs.) was added

[a] Journ. des Min. No. 19, p. 40.

[a] Analyt. Ess. II. p. 28.

and the mixture ignited in a retort; part of the sulphur sublimed, and there remained at the bottom a mass weighing 98 grs. which in colour and chemical properties exactly resembled the original ore. No other substances being detected except oxyd of manganese, carbonic acid, and sulphur, and the weight of the two former being ascertained, the residue is to be considered as sulphur, after deducting 2 per cent. for the usual loss in analyses of this kind. Hence the component parts of the ore may be stated, as

82. White oxyd of manganese.
5. Carbonic acid.
11. Sulphur.

98.

It will not we trust be considered as a mark of disrespect towards the illustrious author of this analysis, if we venture to suggest a few doubts, not with regard to the experiments themselves but the deductions from them.

The only proof of carbonic acid being contained in the ore is that it yielded carbonic acid gas on being heated; but this would have happened if only carbon and oxyd of manganese had been present; again, from the sulphuretted *hydrogen* that was produced by the action of nitric acid on the ore it is highly probable that the manganese was in the metallic state, or at least only very slightly oxygenated: the estimated amount of the sulphur also appears to be much too low; sulphuretted hydrogen contains about 71 per cent. of sulphur, therefore 34 grains of this gas contain 24 grains, to which is to be added one grain of sulphur left in the nitrous solution after the production of the sulphuretted hydrogen, making the whole amount of sulphur equal to 25 grs. The 82 grs. of white oxyd are composed of about 66 of metal and 16 oxygen. It appears therefore more consonant to the analysis, and to known chemical facts, to state the component parts of the sulphuret of manganese, as

66. Manganese.
25. Sulphur.
9. Carbon, oxygen, and loss.

100.

Phosphat of manganese and iron.

It is to Vauquelin[p] that we are indebted for an analysis of this mineral. Having previously ascertained the presence of iron and phosphoric acid in it, he took 100 parts of the ore and boiled it with liquid potash to dryness in a silver crucible; the saline mass hence resulting was lixiviated with distilled water, and the insoluble residue being edulcorated and dried had acquired a deep black colour and weighed something more than the entire mineral. The watery lixivium, containing a considerable excess of alkali was slightly supersaturated with nitric acid, and then boiled in order to expel every portion of carbonic acid that the alkali might accidentally have combined with: lime-water being now poured in, a copious white flocculent precipitate took place which was phosphat of lime, and when well washed and dried weighed 60 parts, indicating 27 of phosphoric acid.

The black part of the ore, which had been insoluble in water, was dissolved in distilled vinegar, and evaporated to dryness; the residue being treated with a fresh portion of vinegar was in part dissolved, a considerable quantity however of red oxyd of iron remained untouched. By repeating the exsiccation till all the iron was deposited, and then gently igniting the deposit, there was procured 31 grains of oxyd of iron. The fluid now containing only acetite of manganese was decomposed by caustic potash, and the precipitate after washing and drying weighed 42 grs. and was oxyd of manganese.

§. 3. *Reduction of Ores.*

As manganese is applied to no use in its metallic state, there are no establishments for the reduction of its ores in the great way; and even in the laboratory the process is seldom performed, chiefly on account of the intense heat which is requisite, and which cannot be obtained in small furnaces unless they are peculiarly well constructed. The use of all alkaline and vitreous fluxes must be carefully avoided; for the affinity of these with the oxyd of manganese is so considerable as entirely to prevent its reduction where they are present. The only method which has been attended with any tolerable success is the following, invented by Bergman.[q] Select a sound and very refractory crucible and line it with charcoal, or still better with a mixture of linseed meal and water, beaten up with as much finely sifted charcoal as it will take without losing its tenacity, dry the crucible thoroughly, gradually increasing the heat till the meal begins to be scorched; then take some oxyd of manganese (purified

[p] An. de Chem. xli. p. 242.

[q] Opuscul. ii. p. 202.

from all extraneous substances as described in the last section) and make it up into a ball with any kind of oil; put this into the cavity of the crucible and cover it with powdered charcoal; then lute on a pierced cover or an inverted crucible, and place it in a blast furnace; keep it at a moderate red heat till the jet of blue flame through the hole in the cover has ceased, then bring the furnace rapidly to its highest heat, and keep it so for forty minutes or three-quarters of an hour: after this let the fire go out, and when the crucible is quite cold break it up carefully and the manganese will be found in globules of various sizes covered for the most part with a thin vitreous crust. It appears probable that a button might be obtained by a second fusion of these globules with glass of borax, in a crucible lined with charcoal and a little pipe-clay to prevent the flux from sinking through the pores of the charcoal.

§ 4. *Physicial and chemical properties of manganese.*[r]

The colour of manganese is greyish-white with a considerable metallic brilliancy. Its fracture is uneven granular: its hardness is somewhat greater than that of cast iron; and it is very brittle. Its sp. gr. according to Bergman, is 6.85, according to Hielm is 7. In fusibility it appears to rank between platina and iron: when pulverized it is feebly attracted by the magnet, but this is probably owing to the presence of iron, from which it is seldom absolutely free.

No other metal is so easily oxydable as this. If a globule of manganese be broken and exposed to the air, the fractured surface almost immediately loses its metallic lustre and acquires a greyish tarnish; in a few seconds more it becomes lilac coloured, then violet, and lastly brownish-black; when in this state, it is friable and breaks down between the fingers into a black powder, resembling in appearance the native grey oxyd. It is by no means however as yet at a high degree of oxydation, for when treated with dilute sulphuric acid it gives out hydrogen gas; after a few days however of exposure to the atmosphere it becomes more saturated with oxygen and then loses this property. When heated below ignition in contact with atmospheric air, nearly the same effect takes place as at the common temperature, only more rapidly.

Chemists at present distinguish three degrees of oxydation of this metal, each of which is characterized by a remarkable change of colour. The white oxyd contains the smallest proportion of oxygen, and the black oxyd the largest; the red oxyd holds an indeterminate place between the two others.

The white oxyd of manganese is most conveniently prepared by adding a carbonated alkali to muriat of manganese; the copious white precipitate that ensues is carbonated manganese, from which by gentle ignition in a small glass retort, the water and carbonic acid is separated, and the white oxyd remains behind. The proportions of the component parts of this oxyd are, according to Bergman, 80 of manganese and 20 of oxygen.

The red oxyd is obtained by mixing two parts of sulphuric acid with one part of black oxyd of manganese and a little water, and boiling the mass to dryness: water digested upon the residuum acquires a beautiful crimson colour, from taking up the red sulphat of manganese thus produced. If now to this red fluid a few drops of carbonated alkali be added, the liquor becomes colourless and a little red oxyd is precipitated, which however turns brown before it can be dried.

No proper analysis has been made of this oxyd, but it is supposed to be manganese with a larger proportion of oxygen than is contained in the white oxyd.

The black oxyd is thus prepared by Bergman. To a solution of the sulphat or any other of the salts of manganese is added some caustic alkali; a brown precipitate immediately falls down, which when washed and dried in an open crucible, at a heat below ignition, acquires a deep brownish-black. From 100 parts of metallic manganese thus treated, Bergman obtained 168 of black oxyd, according to which its constituent proportions are 60 of metal to 40 of oxygen.

The existence of the three oxyds of manganese just mentioned was first ascertained by Bergman, and succeeding chemists, acquiescing in the experiments and deductions of this able philosopher, have done little either to confirm or correct them; it appears to us, however, that the following circumstances respecting the oxyds of this metal taken notice of by Bergman himself, by Scheele, Klaproth, and others, are not perfectly consistent with the received opinions on this subject. Regulus of manganese by exposure to the air for two or three days falls into a pulverulent oxyd of a deep black colour; but that this substance is very different from the perfect black oxyd is

[r] Scheele's Ess. p. 57. Opuscul.

manifest from this, that when digested with dilute sulphuric acid it forms a colourless solution, and at the same time gives out hydrogen gas. Klaproth also observes of this same oxyd, that when kept in the air it exhales for several days a strong odour of hydrogen, proceeding no doubt from the decomposition of the moisture of the atmosphere. Here then appears to be a black, or rather as we believe a *blue* oxyd of manganese, combined with so small a portion of oxygen as to be still capable of decomposing water, and probably much less oxygenated than the white oxyd. It is this oxyd alone which seems capable of uniting with the fixed alkalies by fusion; for if we melt together pearlash and the perfect black oxyd of manganese the result is a saline mass of a blue colour (but green if any yellow oxyd of iron is present) and forming with water a solution of the same tinge. If this solution be largely diluted with water the manganese passes in a short time to the state of red oxyd, and is gradually precipitated: this may arise either from the atmospheric air contained in the water or from a decomposition of part of the water itself. The same effect happens, but more slowly, if the solution is exposed to the air, probably by the combined action of the carbonic acid and the oxygen of the atmosphere, the former uniting with the alkali and the latter with the metallic oxyd. The action of any of the more active acids, for example the sulphuric or muriatic, as might be expected, is similar but more speedy, with only this difference, that if more acid be added than is necessary to saturate the alkali, the excess of acid dissolves the manganese as it passes to the state of white oxyd; forming with it a colourless permanent solution. It is the blue oxyd of manganese alone that seems undecomposable by mere heat, as is manifest from a well-known fact first observed by Rinman, namely, that if the common black oxyd of manganese is exposed for several hours to a white heat, the result is a hardened mass of a green colour; but as the only colouring materials in the common black manganese are iron and manganese, it is obvious that the yellow oxyd of iron must be mixed with the blue oxyd of manganese. Another characteristic of this oxyd is, that it is incapable of combining with acids till by the absorption of a fresh portion of oxygen, it has passed to the state of the white oxyd; as is manifest by its forming with them not a blue but a colourless solution.

The white oxyd of manganese may be exhibited in the least unequivocal manner by adding caustic alkali to a *concentrated* solution of the sulphat or muriat, but if a diluted solution of the metallic salt is employed, the precipitate will be a dusky brown, probably in consequence of the atmospheric air mixed with the diluting water. Bergman's method of preparing the black oxyd in the highest state of oxydation has been already mentioned, but from the uncertainty attending the process it can hardly be considered as an unobjectionable basis on which to found minute calculations. The mode adopted by Klaproth seems much more satisfactory. Having dissolved carbonated manganese in nitric acid to saturation and distilled the mixture to dryness, the whole of the acid was thus separated, and there remained in the retort a grey oxyd of a sparkling metallic lustre, exactly similar in external appearance to the native grey oxyd, and from the circumstances of its formation quite saturated with oxygen. If the native crystallized grey manganese is gently ignited till it ceases to give out oxygen gas, the result is a black powder which seems to be extremely similar to the black oxyd of Bergman; and if this is really the case the black oxyd must be considered as essentially different from the grey, and ranking after it in the order of oxygenation.

Much yet remains to be investigated before the oxyds of manganese are fully understood; the following characters, however, appear to distinguish them sufficiently from one another. The blue oxyd contains the smallest proportion of oxygen: it is soluble in fixed alkalies but not in acids.

The white oxyd is the next in order; it combines with acids, forming colourless salts; it may be converted by ignition in a covered crucible to the state of red oxyd, or to black oxyd by gentle calcination in an open vessel.

The red oxyd is soluble in the sulphuric and muriatic acids, and communicates its own colour to the solution, which may be destroyed by the addition of sugar and other carbonaceous substances: during its solution in the abovementioned acids it gives out no gas.

The black oxyd is of a brownish-black colour; by digestion in cold muriatic acid it forms a deep reddish-brown solution, from which water throws down the whole of the colouring matter; the muriatic solution being heated gives out oxymuriatic acid, and the metal passes to the state of red oxyd. By gentle ignition it gives out little if any oxygen.

The grey oxyd is distinguishable by its metallic lustre, by the quantity of oxygen gas

which it gives out on ignition, by its little solubility in cold muriatic acid, and by the copious production of oxymuriatic acid from these ingredients when heated.

The recently precipitated oxyds of manganese easily pass by exposure to the air from a low to a higher state of oxydation. It has also been asserted by some chemists that the native grey manganese, after its loosely combined oxygen has been driven off by ignition, is capable of again supplying itself with a fresh portion, if made up into a paste with water and exposed for some weeks to the air: this, however, if we may judge from our own experience and the concurring testimony of Dr. Thomson, appears to be a mistake.

We now proceed to consider the action of acids[a] on manganese and its oxyds.

Sulphat of manganese may be prepared in various ways. If metallic manganese and diluted sulphuric acid, are mixed together, a copious effervescence of hydrogen gas takes place, and the metal is rapidly dissolved, leaving behind a black spungy matter, which appears to be carburet of iron. The filtered liquor is perfectly colourless, and affords by evaporation and cooling, large oblique four-sided prisms, which are sulphat of manganese. The white oxyd, either simple or carbonated, may be substituted for the metal with the same result, except that with the former the combination takes place without the extrication of gas, and that with the latter carbonic acid is given out. If the red or either of the more perfect oxyds of manganese be employed, it is necessary to add to the mixture a little sugar or other carbonaceous substance to engage the excess of oxygen, and to apply a boiling heat. Finally, sulphat of manganese may be prepared by putting some black oxyd and water into a Woulfe's apparatus, and throwing in sulphureous acid gas; the black colour of the oxyd disappears by degrees in consequence of a portion of its oxygen being expended in converting the sulphureous to sulphuric acid, which acid, as soon as it is formed dissolves the manganese now reduced to the state of white oxyd, and the result is sulphat of manganese; no gas is disengaged during the whole of this process. This salt readily crystallizes, as we have already mentioned, in oblique prisms; it has an intensely bitter taste, is decomposable with precipitation of its oxyd by the caustic or carbonated alkalies. By dry distillation at a red heat the acid is decomposed, sulphureous acid gas passes over, and the manganese in the state of black oxyd remains behind in the retort.

In the preceding, which is the colourless sulphat, the manganese exists in the state of white oxyd, but it may also combine with sulphuric acid in the state of red oxyd, forming the *red sulphat of manganese*. This salt is prepared by mixing together equal parts of sulphuric acid and black oxyd, and heating the mass in a retort; oxygen gas and a little sulphuric acid pass over, and the dark colour of the mixture disappears; the retort being now withdrawn, and water being added to the saline mass which it contains, a violent heat is produced, and a crimson liquor is obtained, which is the red sulphat. By gradual evaporation it is reduced to a syrupy consistence, and, by carrying on the process farther, to a saline mass; but it refuses to shoot into regular crystals. A large quantity of water partially decomposes it, red oxyd being precipitated; with the fixed alkalies also it yields a red deposit, which shortly becomes brown and then black. By digestion with sugar it becomes colourless, and passes to the state of common sulphat.

Nitric acid, whether colourless or fuming, acts vigorously on reguline manganese and dissolves it, nitrous gas being given out: the solution containing *nitrat of manganese* is as limpid and colourless as water. Pure nitric acid has no action on the black oxyd; but when highly charged with nitrous gas it takes it up without any difficulty, the black colour of the oxyd and the orange of the acid equally disappearing, in consequence of part of the oxygen of the metal having been transferred to the acid. Hence colourless nitric acid may be made to act on the black oxyd by the help of sugar or any similar substance, carbonic acid being at the same time generated. Nitrat of manganese is deliquescent and uncrystallizable.

Muriatic acid dissolves reguline manganese, hydrogen gas being given out, and the solution is clear and colourless. When digested on the white oxyd it also forms a similar colourless *muriat of manganese*. If muriatic acid is boiled on the black oxyd, part of the acid becomes converted into oxymuriatic gas at the expence of the oxyd, while the remainder of the acid dissolves the manganese now converted into the white oxyd. If muriatic acid and the black oxyd be digested together for a few hours *in the cold*, no oxymuriatic acid is extricated, the solution is of a reddish-brown colour, and pro-

[a] Scheele's Ess. p. 68. Bergman Opuscul. II. p. 210.

bably consists of a mixture of muriatic and oxymuriatic acids combined with the red oxyd. The simple addition of water throws down a red precipitate, and usually discharges the whole colour from the solution. By ebullition oxymuriatic acid is set at liberty, and the solution becomes much lighter, still however retaining a faint reddish tinge. Reguline manganese, when pulverized and thrown into a vial of oxymuriatic acid gas undergoes inflammation, and is converted into the white oxyd.

Both the regulus and oxyds of manganese are soluble in water highly impregnated with carbonic acid; when the former is made use of an odour like burning fat is perceivable, owing probably to the decomposition of water and consequent extrication of hydrogen gas. When the solution is exposed to the air, part of the carbonic acid escapes and insoluble carbonat of manganese is separated in the form of a thin white pellicle.

The fluoric, boracic, and phosphoric acids, exert but little direct action on manganese and its oxyds, but by adding the neutral salts of these acids to the sulphat or muriat of manganese, a white and little soluble precipitate falls down, consisting of oxyd of manganese combined with the added acid.

Acetic acid by long digestion becomes saturated with oxyd of manganese, whether the metal or any of its oxyds are made use of; it does not crystallize on evaporation, but affords a deliquescent mass. But the most expeditious way of saturating acetic acid with manganese is to digest the acid upon the recently precipitated carbonat as long as any gas is disengaged.

Citric acid by digestion in the cold with the black oxyd of manganese, takes up a part and becomes itself of a brown colour; if this solution is then exposed to heat an effervescence ensues, occasioned by the escape of carbonic acid, and the fluid becomes colourless.

Tartareous acid acts precisely in the same manner as the preceding.

Oxalic acid dissolves the black oxyd of manganese with effervescence, and the solution when saturated deposits a white crystalline powder, which is oxalat of manganese.

The action of the other acids on manganese has been but little ascertained; all that we know is that they may be formed by digestion with the recently precipitated carbonat of manganese, the carbonic acid being separated in the state of gas.

The action of the fixed alkalies on the oxyds of manganese has already been described; it only remains to remark in addition, that if to the blue or green mass produced by the fusion of fixed alkali and oxyd of manganese there be added a little charcoal-powder, and the whole be exposed to a melting-heat, a slight effervescence in a short time takes place, and the colour gradually changes to yellowish-white.

Ammonia by exposure to black oxyd of manganese at a red heat is entirely decomposed, its hydrogen uniting with part of the oxygen forms water, and the azot, its other element, by combination with a further portion of oxygen, produces nitrous acid, as may be seen more at large under the article Ammonia.

Nitre and the black oxyd being distilled together, nitrous acid and oxygen gas pass over; what remains in the retort is a blue mass, consisting of oxyd of manganese and potash.

Muriat of ammonia, by dry distillation with the black oxyd, gives out its ammonia, of which part passes off undecomposed, but the residue, with the liberated oxygen of the manganese, forms water and azot.

The black oxyd, when fused with borax or any of the vitrescent mixtures, communicates to the mass an amethyst-red colour which is discharged by charcoal or any other deoxygenating substance and restored by nitre. For a full account of the curious and intricate phenomena, which it exhibits when fused with glass, see that article.

Sulphur, according to Bergman, appears to have no action on reguline manganese. But if the black oxyd be ignited in a retort with half its weight of sulphur, there comes over a quantity of sulphureous acid gas, part of the sulphur sublimes, and there remains in the bulb of the retort a yellowish-green mass, equal in weight to the oxyd employed and nearly half of the sulphur. The manganese in this sulphuret seems to be very nearly if not quite in the reguline state; for when digested with muriatic or dilute sulphuric or nitric acids, sulphuretted hydrogen gas is liberated, the manganese is dissolved, and a few grains of sulphur alone remain in the fluid. By calcination in an open vessel the sulphuret is more or less decomposed, part of its sulphur escapes, and the residual mass acquires a brown colour; if in this state it is lixiviated with water a considerable portion dissolves, and the fluid by evaporation and cooling deposits crystals of sulphated manganese: the insoluble residue, by the addition of a little sulphur and subsequent calcination, may be wholly converted into sulphat.

The alkaline hydrosulphurets and hydro-

guretted sulphurets separate the oxyd of manganese from its acid solutions in the form of a white powder, the properties of which, however, have not been examined.

Phosphuret of manganese has only been described by Pelletier.[b] If equal parts of vitreous phosphoric acid and reguline manganese, together with charcoal equal in weight to $\frac{1}{15}$ of the other two ingredients, are accurately mixed in a mortar, and afterwards exposed to a strong heat in a covered crucible, the result will be a button of a white colour and metallic lustre; hard, brittle, of a granular fracture, permanent in the air, and much more easily fusible than the pure regulus. By fusion before the blowpipe the phosphorus burns out, and the metal is converted to a black oxyd.

Oxyd of manganese and the expressed oils exert a considerable action on each other. If one part of finely pulverized black oxyd and four parts of olive oil are digested together, when the mixture begins to get moderately warm, a violent effervescence takes place, owing to the extrication of carbonic acid, and when this ceases the manganese is found to be entirely dissolved in the oil, which, when cold, acquires the consistence of salve.

The alloys of manganese are of little importance, and have not yet been subjected to much chemical investigation. For its alloys with gold, lead, copper, and iron, see the accounts of those metals respectively.

If white arsenic and oxyd of manganese are heated together, the former is volatilized without at all combining with the latter; but if arseniat of potash and any of the salts of manganese are mixed together, a precipitate of arseniat of manganese is thrown down; this being mixed with a little charcoal and heated in a covered crucible, runs down into a dark-coloured easily fusible metallic button, from which, by continued heat in an open vessel, the arsenic is almost entirely volatilized, leaving the manganese behind in the state of black oxyd.

The only use of manganese is in the state of black oxyd. It is employed in the laboratory as the cheapest and most convenient material from which to procure oxygen gas. All the oxymuriatic acid consumed in the bleacheries of Britain, France, and Germany, is prepared from manganese and the usual materials of muriatic acid. Finally it is largely employed by the glass-makers, both as a colouring material and for the purpose of destroying the colour of the finer kinds of glasses; hence its common appellation of *glass soap*. It may be remarked by the bye that this latter application of manganese to the purposes of art is by far the most ancient, it being distinctly mentioned by Pliny in his Natural History, whereas the others do not date further back than the commencement of pneumatic chemistry.

MANHEIM GOLD. See COPPER (*Alloys of*), p. 347.

MARBLE. See LIMESTONE.

MARCASITE. See ARSENICAL Pyrites, p. 93.

MARINE ACID. See MURIATIC ACID.

MARL.

Of this mineral there are the two following subspecies.

1. *Subsp.* Earthy marl. *Mergel erde*, Wern. *Marne terreuse*, Broch.

Its usual colour is yellowish-grey, passing sometimes to Isabella-yellow, also ash-grey, yellowish and greyish white. It is dull, and is composed of more or less cohering dusty particles; it soils a little, is meagre, and somewhat rough to the touch. It is light, sometimes almost sufficiently so as to float on water.

It effervesces powerfully with acids, and is readily fusible by the blowpipe.

It occurs in beds in secondary limestone and the more recent sandstone, and frequently contains shells. It is employed in pottery, but its most important use is in agriculture as a manure for sour clay, sand, or peat.

2. *Subsp.* Indurated marl. *Verhärteter mergel*, Wern. *Marne endurcie*, Broch.

Its colour is smoke-grey, yellowish, bluish, or blackish grey, yellowish-white, ochre-yellow, and brownish-red. It occurs in mass. It is dull, sometimes slightly glimmering from an admixture of foreign particles. Its fracture is earthy, or splintery passing into conchoidal, or slaty. It breaks into indeterminately angular or slaty fragments. It is opake, moderately soft, brittle, and easily frangible.

Like the preceding it forms a greyish-black glass before the blowpipe, and effervesces vigorously with acids.

It occurs principally in secondary limestone, alternating in beds with it or forming nests in it: it is also met with in the independent coal formation.

It readily disintegrates by exposure to the weather, and is in great request with the farmer. It frequently contains shells.

In agriculture the following varieties of marl are usually distinguished.

[b] Memoires.

Common marl, which includes not only the earthy marl but some varieties of potters clay: stone marl, which is the earthy indurated; slate marl, which is the slaty indurated; and shell marl, which is either the earthy or indurated, abounding with shells.

MARLITE, *bituminous*, Kirw. *Bituminöser mergelschiefer*, Wern. *Schiste marno-bitumineux*, Broch.

Its colour is greyish or brownish black. It occurs in mass. The surface of its fracture is either rough and dull or slightly glimmering, or smooth and glistening or shining.

Its fracture is plane or waved slaty. Its fragments are slaty. It is opake, acquires a polish by friction, is soft, easily frangible, somewhat meagre to the touch, and moderately heavy.

It effervesces with acids, and when exposed to the blowpipe gives out a bituminous odour and a weak flame, and then fuses into a black scoria.

It occurs in beds with the oldest secondary limestone. It is often mixed, more or less, with various ores of copper, especially the pyritical and vitreous; also more rarely with the blue or green carbonated or native copper. When this is the case it is often regularly worked as an ore of copper.

A remarkable circumstance relating to this mineral is, that it contains petrified fish and vegetable remains, arranged in regular bands; the bodies of the fish are carbonized, and their scales often plated with copper ore: notwithstanding the regularity of the layers each fish is in a contorted and convulsed position, as if it had suddenly undergone a violent death.

It occurs at Eisleben and Ilmenau in Thuringia, and Riegelsdorf in Hessia.

MARTIAL ETHIOPS. See Iron, p. 612.

MARTIAL FLOWERS. See Iron, p. 622.

MARTIAL REGULUS OF ANTIMONY. See Antimony, p. 80.

MARTIAL TINCTURE. See Iron, p. 622.

MARTIAL VITRIOL. See Iron, p. 614.

MASSICOT. See Lead.

MASTICH.[a]

The pistachia lentiscus is a small tree, about ten or twelve feet high, that grows in several of the islands of the Archipelago, but is cultivated with peculiar care and success in the island of Chio. In the month of August transverse incisions are made in the bark of this tree, from which there oozes out in the space of a few hours a pellucid resin. This resin is called mastich, and when pure is in the form of little round drops or tears, of a very pale amber colour; a piece recently broken is quite transparent, but by exposure to the air it becomes somewhat pulverulent superficially, and hence semitransparent. Its sp. gr. is 1.074. This resin, especially when gently warmed, has a faint but not unpleasant odour, which becomes stronger and more grateful when it is melted; it has scarcely any sensible flavour; when masticated it grows soft like wax, and acquires an ivory whiteness; water boiled upon it becomes impregnated with its odour, but the mastich loses hardly any weight by the process.

In its habitudes with acids and alkalies mastich does not perceptibly differ from the other resins. By digestion with alcohol it is separated into two portions; the one soluble in this fluid and the other insoluble; the former composes about $\frac{4}{5}$ of the whole, and is pure resin; the latter in most of its properties closely resembles caoutchouc. The presence of this substance in mastich was first remarked by Kunde, an apothecary of Berlin, whose observations have since been confirmed by Mr. Matthews.[b] After solution of the resin in alcohol an inflammable residue is left behind of a white colour, considerably elastic and adhesive; when heated it becomes brown, emitting an inflammable gas, and in this state greatly resembles common caoutchouc, except in being slightly glutinous. It is perfectly soluble in washed sulphuric ether from which it is precipitable by alcohol in the form of a white curd. It is wholly insoluble in water. By digestion with nitric acid it is converted into a yellow brittle porous mass, nitrous gas being at the same time given out; it is charred by sulphuric acid, to which it communicates a deep (somewhat muddy) crimson colour, with the evolution of sulphureous acid. Neither the muriatic nor oxymuriatic acids, nor the alkalies whether caustic or carbonated, have any action on it: in all which particulars it agrees with caoutchouc.

In the Turkish dominions mastich is in great request among the women, as a masticatory, and the produce of the Chian plantations is said to be appropriated to the use of the emperour's seraglio. In the other countries of Europe it is employed medically in fumigations, and by painters and other artists in the composition of the tougher kinds of varnishes.

MATRASS, an article of chemical apparatus. See Appendix.

[a] Murray's Apparat. Med. I. p. 127.

[b] Nich. Journ. x. p. 247.

MATT. The produce of the first fusion of a sulphuretted ore is called a *matt*, a term probably adopted from the German miners; for the word in that language signifies dull, without lustre, a character that is applicable with great justice to most of the half sulphurized reguli when compared to the same metals in their pure state.

MEASURES and WEIGHTS. See the APPENDIX.

MEERSCHAUM[a] Wern. Ecume de mer, *Froch.* Keffekil, *Kirw.*

Its colour is yellowish-white passing to Isabella-yellow, or greyish or reddish. It occurs in mass. It is dull. Its fracture is fine-grained, earthy, passing into flat conchoidal, or small slaty; its fragments are indeterminately angular, moderately sharp-edged. It is opake, soft, easily frangible, acquires a polish by friction, is more or less unctuous to the touch, sp. gr. 1.6.

It is partly soluble in acids without effervescence, and is infusible, without addition, before the blowpipe.

It has been analysed both by Wiegleb and Klaproth with the following results:

	Wiegleb	Klaproth	
Silex	54.16	50. 5	41
Magnesia	51.66	17.25	18.25
Lime	——	0.5	0.5
Water	——	25. }	39.0
Carbonic acid	——	5. }	
	105.82	98.25	98.75

Much of the apparent difference between these analyses will be removed by observing that Klaproth analysed the fresh earth, whereas the specimen examined by Wiegleb was a tobacco pipe made of the same earth, but of course baked, and therefore deprived of water and carbonic acid. A third specimen analysed by Klaproth yielded considerably more magnesia and less silex than the other two, and therefore approached nearly to that examined by Wiegleb.

Meerschaum is used in various parts of the Turkish dominions as fullers' earth is with us; it is also employed by the Turkish women instead of soap in washing their hair, the bowls of the Turkish pipes are also made of it.

The most valued sort of this mineral is found in the Crimea, whence it used to be exported in great quantity to Constantinople under the name of keffekil, or earth of Kaffa, so called from the town in the Crimea where it was shipped. It is also found in Natolia, and the Islands of Samos and Negropont in the Archipelago. It forms thin beds, and when recently dug, is said to be in a soft pasty state, but becomes harder by exposure to the air.

An earthy substance, similar to the above, has been found by Fabbroni at Castel del Piano, near Sienna: it consists of 55 silex, 25 magnesia, 12 alumine, 3 lime, and 0.1 oxyd of iron; and is the material of which he has made bricks so light as to float in the water; thus restoring one of the lost arts recorded by Strabo and Pliny.

MELANITE[b]. Melanit, *Wern.* Black garnet of most mineralogists.

Its colour is velvet-black inclining to greyish-black. It occurs crystallized in six-sided prisms, terminated at each extremity by an obtuse trihedral pyramid, the planes of which are set on the alternate edges of the prism; the prism itself is not unfrequently truncated on its lateral edges. Its crystals are middle-sized and small. Externally it is smooth and shining, approaching to resplendent; internally it is shining, approaching to glimmering. Its fracture is imperfectly flat conchoidal, with sometimes a tendency to foliated: its natural joints obliquely intersect each other in two directions. Its fragments are indeterminately angular and sharp-edged. It is opake, hard, pretty easily frangible, sp. gr. 3.69 to 3.8.

Both Klaproth and Vauquelin have published analyses of this mineral, but they differ so considerably as to render it probable that the one or the other has operated on a different substance from the true melanite. The following are the results.

	Klapr.	Vauq.
Silex	40	35
Alumine	28.5	6
Lime	3.5	32
Magnesia	10.	0
Oxyd of iron	16.5 }	25
Ditto of manganese	0 25 }	
	98.75	98

It has hitherto been found only in Italy, at Frascati, and St. Albano, near Rome.

MELLITE or HONEYSTONE.[c] *Honigstein*, Wern. *Mellilite*, Kirw. *Mellite*, Broch. *and* Hauy.

Its colour is honey-yellow, passing into pale wax and straw yellow. It occurs in detached grains, and crystallized. Its primitive figure is an octohedron, formed by two four-sided pyramids, the common base of which is a perfect

[a] Brochant. Jameson. [b] Jameson. Brochant. [c] Brochant. Hauy. Jameson.

square, and the incidence of each face in one pyramid, on its corresponding face in the other pyramid is = 93°. 22'. Besides the above form it presents the two following varieties.

1. The primitive octohedron with all the solid angles replaced by small quadrilateral planes, the surfaces of which are not unfrequently curvilinear.

2. The primitive octohedron with the lateral angles deeply truncated, thus forming a dodecahedron, differing however in the measurement of its angles from the rhomboidal or garnet dodecahedron.

The crystals are small, and very small; their surface is commonly smooth and shining. Internally it is splendent with a lustre between vitreous and resinous. Its fracture is perfectly conchoidal; its fragments are indeterminately angular It is transparent, passing into opake, and possesses a double refraction. It is softer than amber; is brittle, and easily frangible. Sp. gr. 1.58 to 1.66. It becomes electric by friction, but continues so only for an instant.

When ignited in the open air it first becomes opake, and of a greyish-white spotted with black, at length it acquires the colour and consistence of chalk; no smoak or flame are observable during the whole of this process.

According to the experiments of Klaproth[b] it exhibits the following properties.

When finely pulverized, and boiled with a large quantity of water, it forms an acidulous solution, and leaves behind a light-grey slimy earth.

It is entirely soluble in nitric acid without heat. With muriatic acid it affords a somewhat turbid solution. In concentrated sulphuric acid it breaks down into a white flocculent matter, which, by subsequent dilution with water, is entirely taken up.

A solution of caustic soda first converts mellite into a loose flocculent substance, and then dissolves the greater part of it.

Ammonia, by cold digestion for some hours in a closed bottle, produces a compleat disintegration: the earthy part is left behind in the form of a greyish slime, and the acid combines with the ammonia into a crystallizable fluid.

Mellite, projected on melted nitre, causes a slight scintillation, and the white earthy part remains mixed with the saline residue.

When boiled with a solution of carbonated soda, a moderate effervescence takes place, and when this ceases, there remains a white earth, which is alumine, with a small casual admixture of silex. The supernatant liquor, when exactly neutralized with acetic acid, and evaporated to dryness, leaves behind a saline mass, which, after the acetat of soda has been washed out by alcohol, furnishes by solution in water and evaporation crystals of a neutral salt. Hence mellite consists essentially of an acid and alumine.

The most satisfactory of the analyses performed on this substance by Klaproth, is the following.

a. 400 grains of mellite reduced to a fine powder were boiled three several times with 60 ounces of distilled water each time: there remained behind an earthy residue weighing, after being dried, 210 grains.

b. The watery solution being concentrated in a gentle warmth, till it became thick, was mixed with alcohol, by which it acquired a pitchy consistence, but at length by continued trituration, it dissolved in this fluid, with the exception of some earthy flocculi, which, when washed and dried, weighed 22 grs. When these were separated, the clear liquor yielded, by evaporation, a brownish saline mass, weighing 92 grains.

c. This brown salt, by two successive evaporations and solutions, was procured in distinctly crystallized needles, and was pure *mellitic acid*.

d. The insoluble residues of *a* and *b*, by exposure to a red heat, gave out a weak sweetish odour, owing to the combustion of a small portion of acid, and were reduced to a greyish white powder, weighing 64 grs. This, when treated with four times its weight of strong sulphuric acid, coagulated into a crystalline mass, which, by re-solution in water, left behind 11 grs. of residue.

e. These 11 grs. by digestion with muriatic acid were reduced to 5.5 which were *silex*.

f. The muriatic solution of *e* afforded, with prussiat of potash, a small portion of blue precipitate, indicating 0.5 gr. of *iron*.

g. From the clear solution of *f*, carbonated soda threw down some alumine, which being redissolved in sulphuric acid, was added to the sulphuric solution of *d*. By the addition of acetat of potash, the whole shot into crystals of alum, which, when treated with carbonat of ammonia, afforded *alumine* to the amount of 58 grs. after ignition.

Hence these 400 grs. of mellite are composed of

5.5	Silex
0.5	Iron
58.0	Alumine
336.0	Mellitic acid, water, and loss

which gives *per cent*.

[b] Analyt. Ess. II. p. 93.

1.375	Silex
0.125	Iron
14.5	Alumine
84.	Mellitic acid, water, and loſs
100.000	

Mellite is a mineral of very rare occurrence, having hitherto been found only at Aertern in Thuringia, Langenbogen in the diſtrict of Saal, and in Switzerland. It occurs on bituminous wood, and earthy coal, and is generally accompanied by ſulphur.

MELLITIC ACID.[a]

This acid obtained as mentioned in the preceding article, cryſtallizes in finely fibrous and ſpherical maſſes, or in minute ſhort priſms. Its taſte is ſweetiſh-ſour with a bitteriſh flavour. It is decompoſed by ignition into a dark-grey ſmoak, poſſeſſing very little odour, and leaves behind a ſmall portion of aſhes that are neither alkaline nor acidulous. It is not convertible into oxalic acid by digeſtion with nitric acid. If dropped into a ſolution of cauſtic lime, barytes, or ſtrontian, it immediately produces a white precipitate, which, however, is again taken up by muriatic acid. It decompoſes acetat of barytes, acetat of lead, nitrat of mercury, and nitrat of iron, but all theſe precipitates are reſoluble in nitric acid. It produces no change in nitrat of ſilver or muriat of copper. When added to muriat of barytes, it cauſes no alteration at firſt, but ſoon brings on a copious depoſit of cryſtalline needles.

With potaſh it forms a neutral ſalt, of a ſtriated cryſtalline appearance.

With ſoda it affords cryſtals in the form of cubes or triangular plates.

With ammonia it affords clear hexahedral priſms, which, by expoſure to the air, loſe their tranſparency, and acquire a ſilvery-white appearance.

MENACHANITE. See TITANIUM.

MENSTRUUM.

This term is nearly ſynonimous with SOLVENT, which ſee.

MERCURY or QUICKSILVER. *Mercure, Argent vif*, Fr. *Queckſilber*, Germ.

Mercury is a metal of a ſilvery-white colour, and fluid at the uſual atmoſpherical temperature.

§. 1. *Ores of Mercury.*[a]

Sp. 1. Native Mercury. *Mercure natif*, Broch. *Gediegen Queckſilber*, Wern.

Its colour is between tin and ſilver-white. It occurs diſſeminated in globules of various ſizes, or collected in the cavities of mines. It has a very brilliant metallic luſtre, is opake, perfectly fluid, cold to the touch, and does not adhere to the fingers. Sp. gr. 13.56.

Native mercury is generally very pure, but ſometimes it contains a little ſilver, thus forming an intermediate variety between this ſpecies and the next. In proportion to the amount of the ſilver its fluidity is diminiſhed.

It occurs in marlite, calcareous ſpar, indurated clay, argillaceous ſchiſtus, quartz, &c. accompanied for the moſt part by cinnabar and pyrites.

It is met with in the mines of Idria in Carniola, at Moſchellandſberg in Deux Ponts, Almaden in Spain, and Guanca Velica in Peru.

Sp. 2. Native Amalgam. *Amalgame natif*, Broch. *Naturliches Amalgam*, Werm. *Mercure Argental*, Hauy.

Its colour is ſilver-white or greyiſh, ſometimes irideſcently tarniſhed. It occurs rarely in maſs, more commonly diſſeminated, inveſting, in ſmall veins or cryſtallized. The forms of its cryſtals are,

1. The regular octohedron truncated on the edges.
2. The rhomboidal dodecahedron.
3. The preceding truncated on the edges.

The cryſtals are ſmall and very ſmall, and for the moſt part ill determined. Its ſurface varies from much to little ſhining, according as it is ſmooth or rough. Internally it is ſhining or little ſhining, with a metallic luſtre. Its fracture is uneven, paſſing into flat conchoidal. It is ſoft, often very ſoft. It is more or leſs brittle according to the proportion of ſilver that it contains. It creaks when cut; and is very heavy.

On expoſure to the blowpipe the mercury is volatilized, and a bead of pure ſilver remains behind. A cryſtallized ſpecimen, analyſed by Klaproth, afforded

Silver	36
Mercury	64
	100

In ſome of the paſty ſemifluid varieties however, the proportion of ſilver is as low as 10 per cent.

It has ſometimes been miſtaken for native ſilver, but may be at once diſtinguiſhed by its property of whitening gold when rubbed upon it.

It occurs only in thoſe mines where veins of mercury are croſſed by or mixed with others of

[a] Klaproth. [a] Lenz. Born. Emmerling. Brochant. Kirwan. Hauy. Jameſon.

filver. Hence it never occurs in the mines of Idria or Almaden, but is far from rare in thofe of Rofenau, in Upper Hungary; it is alfo met with at Sahlberg in Sweden, Mörsfeld, in the Palatinate, and Mofchellandfberg, in Deux Ponts.

It is ufually found in red and grey indurated clay, accompanied by native mercury, fpathofe iron ore, grey antimony, and grey copper.

Sp. 3. Liver-coloured mercurial ore. *Queckfilber lebererz*, Wern. *Mercure hepatique*, Broch. Of this fpecies there are the two following varieties.

1 *Var.* Compact.

The colour is intermediate between dark cochineal red and lead-grey. It occurs maffive. Internally it has a gliftening femi-metallic luftre. Its fracture is even, paffing into fine grained uneven, or imperfectly flat conchoidal. Its fragments are indeterminately angular, fomewhat blunt edged. It is opake; receives a polifh by friction, and gives a ftreak of a cochineal red colour. It is foft, may be cut by a knife, and is eafily frangible, fp. gr. 7.18 to 7.93.

2 *Var.* Slaty.

Its colour is the fame as the preceding, only a little more red. It occurs in mafs. Its longitudinal fracture is fhining with a metallic luftre; its crofs fracture is only glimmering. Its longitudinal fracture is thick and curved flaty; its crofs fracture is compact and even. Its fragments are flaty; it is opake, and very eafily frangible.

Both thefe varieties are mixed with cinnabar, native mercury, iron pyrites and clay. The produce of mercury varies from lefs than 20 to more than 70 per cent; the compact is ufually the richeft, containing a lefs proportion of earthy matter than the other. It has not been analyfed with much accuracy, but it appears that at leaft a confiderable portion of its mercury is in the ftate of fimple red oxyd.

It occurs in abundance at Frioul in Iftria, Almaden in Spain, in the Duchy of Deux Ponts, and Nertfchinfk in Siberia.

Sp. 4. Bituminous mercurial ore.

Of this there are the two following varieties.

1. *Var.* Branderz.

This is a kind of coarfe coal of a reddifh-black colour. It occurs in mafs, or in balls diffeminated through bituminous fhale. When heated it takes fire, and burns with a white flame.

2. *Var.* Corallenerz.

This is the bituminous fhale in which the balls of the preceding variety are implanted, and, like that, it burns when heated, with a white flame.

The bituminous mercurial ore occurs at Idria in Carniola, and Nertfchinfk in Siberia, in confiderable abundance: it contains from 2 to 20 per cent. of mercury. It has not been analyfed, but it is certain that part of the mercury that it contains is in the native ftate, the reft is fuppofed for the moft part to be in the ftate of muriat.

Sp. 5. Cinnabar. *Zinnober*, Wern. *Cinnabre*, Broch.

Of this there are the three following fubfpecies.

1. *Subfp.* Common, or dark red, C. *Dunkel rother*, Z. Wern.

Its colour is cochineal-red, which in fome varieties paffes to carmine-red, and in others to lead-grey. It occurs in mafs, diffeminated, invefting, cellular, dendritic or cryftallized. The primitive form of its cryftals is the regular hexahedral prifm, befides which the following varieties occur.

1. The fame with three alternate terminal edges of the prifm deeply bevilled.
2. A tetrahedral pyramid.
3. An octohedron, compofed of two tetrahedral pyramids.
4. A fingle trihedral pyramid.
5. A double trihedral pyramid, either with or without an intervening trihedral prifm.
6. The fame as *var.* 1. curved into a lenticular form by the addition of feveral irregular truncatures.

The cryftals are fmall, and very fmall, and ufually occur in clufters. The cryftals are fplendent externally and internally, are more or lefs fhining with almoft a femi-metallic luftre. Its fracture is fine-grained uneven, fometimes even and conchoidal; alfo as it approaches to the cryftalline ftate, more or lefs perfectly foliated. Its fragments are indeterminate and blunt-edged. The foliated varieties prefent fine-grained diftinct concretions. The maffive cinnabar is opake, or at moft tranflucent on the edges; the cryftallized is tranflucent, and femitranfparent. It acquires a luftre by friction, and when pulverized is of a fcarlet-red colour. It is foft, may be cut with a knife, and is eafily frangible. Sp gr. of the compact, when moderately pure, 7.2 to 7.3; of the cryftallized, 10.12. Its conftituent parts according to Lampadius are

81.	Mercury
15.2	Sulphur
4.7	Iron
100.9	

Before the blowpipe it is almost entirely volatilizable with a blue flame, and a sulphureous odour.

Cinnabar occurs in two distinct rock-formations. It is found most abundantly in the independent coal-formation: also in beds interposed between primitive argillaceous schistus and chlorite slate, accompanied by quartz, calcareous spar, spathose iron, micaceous iron, and iron and copper pyrites.

The most abundant European mines of Cinnabar are at Idria in Carniola, and Almaden in Spain, in the independent coal-formation. It occurs more sparingly in primitive strata at Mörsfeld in the Palatinate, Moschellandsberg in the territory of Deux Ponts; also in Saxony, Bohemia, Hungary, and Transylvania. It is met with in Japan, Kamtschatka, and Siberia in Asia, and near Guanca Velica in Peru.

2. *Subsp.* Fibrous cinnabar. *Hochrother, Z.* Wern.

Its colour is bright scarlet, passing to crimson and Aurora-red. It occurs in mass and disseminated. Internally it is glimmering with a silky lustre, but its cross fracture is dull. Its fracture in one direction is fine-grained earthy, in the other is minutely fibrous. Its fragments are indeterminately angular, blunt-edged; it is opake; acquires a slight polish by friction, and when pulverized is of a scarlet-red. It stains the fingers in a small degree; is very soft, passing to friable; may be cut with a knife; and is of great specific gravity.

It is a rare mineral, and is always accompanied by the preceding subspecies: it is principally found in the Palatinate.

3. *Subsp.* Hepatic Cinnabar. *Cinnabre alcalin*, Born.

Its colour is bright-red; it occurs in mass; its fracture is foliated; its fragments are rhomboidal; it is transparent. By friction it exhales a very strong odour of sulphuretted hydrogen. It occurs in white calcareous spar at Idria in Carniola.

Sp. 6. Horn Mercury. *Queckfilber Hornerz*, Wern. *Mine de mercure cornée*, Broch.

Its colour is ash-grey, passing into yellowish-grey, greyish-white, and greenish-grey; when penetrated as it sometimes is with native mercury it is blackish-grey. It occurs very rarely in mass, most frequently in small and thin tubercular crusts, the cavities of which are lined with minute crystals, also in small globules formed by the aggregation of crystals. The only well ascertained form of its crystals is a dodecahedron composed of a four-sided prism terminated by tetrahedral pyramids: the planes of the prism are hexagons, those of the summits are rhombs. The crystals are generally very small and splendent. Internally they are splendent with a diamond lustre, passing sometimes to metallic. The fracture as far as it can be observed is strait lamellar. It sometimes presents fine-grained distinct concretions. It is faintly translucent; soft; may be cut with a knife, and is easily frangible.

On exposure to the blowpipe it is totally volatilized without decomposition. It is soluble in water, and the solution gives an orange-coloured precipitate with lime-water. The only analysis of this mineral that we possess is an imperfect one by M. Woulfe, the discoverer of it, from which it may be concluded, with considerable probability, that it consists when pure of about

64	Sulphat of mercury
36	Muriat of mercury
100	

It occurs in the quicksilver mines of the Palatinate, and Deux Ponts; at Idria, Horsowitz in Bohemia, and Spain.

§. 2. *Analysis and Assay.*

There are no very exact analyses of any of the mercurial ores, but the following methods of examining them seem to be liable to little or no objection.

The *native mercury* and *native amalgam* may be thus analysed. Let the ore be digested in moderately strong nitric acid, which will take up the mercury, and silver, and bismuth, if there should chance to be any present: a minute quantity of gold may also be contained in the argentiferous mercury, which will be left untouched at the bottom of the solution, in the form of a brown powder. The nitrous solution being concentrated by gentle evaporation, till it is on the point of crystallizing, is to be poured into a large quantity of pure water, by which the bismuth will for the most part be separated. Having thus got rid of the bismuth, add to the filtered liquor a solution of common salt or any other neutral muriat, by which both the silver and mercury will be thrown down in the state of muriat. This being separated, drop into the clear liquor some carbonated alkali as long as any precipitate takes place, then boil the liquor, and separate the precipitate by filtration. The muriatic precipitate is now to be digested in moderately dilute nitro-muriatic acid, which

will take up every thing but the muriat of silver, from which, when washed and dried, the amount of silver in the ore may be readily ascertained. Now decompose the nitro-muriatic solution at a boiling heat by carbonated alkali, and add the white precipitate thus obtained to the other carbonated precipitate; mix these with a little oil or sugar (the latter is the best) and proceed to distillation in a small coated glass retort; raise it gradually to ignition, and continue it at that temperature as long as any mercury comes over. What remains behind is a little metallic bismuth and charcoal.

Cinnabar may be analysed in the following manner. After being reduced to a fine powder, let it be digested repeatedly in a mixture of 3 parts muriatic acid and 1 nitric, the whole moderately diluted; by this every thing will be taken up except the sulphur and the silex. This residue being washed, dried, and weighed, is to be ignited, and the remaining silex being deducted, the difference of weight indicates the amount of the sulphur. The nitro-muriatic solution being decomposed by carbonated alkali at a boiling heat, and the precipitate thus obtained being mixed with a little lamp-black and distilled, the mercury will pass over in the metallic state: what remains in the retort is magnetic oxyd of iron, and the casual earth (excepting silex) contained in the ore, together with a little charcoal, which may be separated in the usual way.

The *liver-coloured* and *bituminous ores* may be treated exactly in the same manner as the preceding; but as these ores sometimes contain a little silver, the matter insoluble in nitro-muriatic acid may be not merely sulphur and silex but muriat of silver; after therefore the sulphur is burnt off, the residue mixed with twice its weight of pearlash is to be strongly ignited in an earthen crucible, and then treated with dilute muriatic acid which will take up the alkali and earth leaving behind the silver in small metallic grains.

The best way of analysing the horn mercury is to digest it in a little distilled vinegar, by which the native mercury which is sometimes dispersed through it will be left behind. To the clear solution add nitrat of barytes, which will separate the sulphuric acid in the state of sulphat of barytes: this being taken out, drop in nitrat of silver, which will separate the muriatic acid in the state of muriated silver. The mercury, now in the state of nitrat, remains in solution, and may be exhibited in the metallic state by precipitating it by means of iron and subsequent washing in muriatic acid; or by throwing it down by a carbonated alkali, and distilling the precipitate with a little lamp-black.

The assay of mercurial ores in the dry way is very simple. The specimen being pulverized, and accurately mixed with ¼ of its weight of quicklime and an equal portion of iron filings, is to be pretty strongly ignited in an iron or earthen retort as long as any mercury comes over into the receiver.

§. 3. *Reduction of ores.*

The modes of extracting the metal from the ores of mercury are very simple. The first that we shall mention is the best and most scientific, and practised at the mines of Deux Ponts, and of Idria. The ore being brought out of the mine, is sorted by hand with considerable accuracy, rejecting those parts that appear to be destitute of metal. This is an expensive and rather tedious process, but has superseded the ancient method of separating the cinnabar by washing, on account of the prodigious loss of metal in that operation. The sorted ore being reduced to powder is carefully mingled with ⅕ more or less, according to the proportion of cinnabar contained in the ore, of quicklime which has fallen to powder by exposure to the air. This mixture is then put into iron retorts, capable of holding about 60 lbs. weight, which when thus charged, are fixed in a long furnace, to the number of 40 or 50: a glass receiver being then attached to each retort, but not luted, a gentle fire is applied in order to drive out all the moisture; when this is effected, the juncture of the vessels is closely stopped with tempered clay, and a full red heat is applied for seven or eight hours, at the expiration of which time all the mercury will have been volatilized and condensed in the receiver. The common produce varies between six and ten ounces of metal from 100 lbs. of the ore.

The method practised at Almaden, in Spain, differs considerably from the preceding, and is much more rude and inartificial. The pieces of pure cinnabar being first picked out from the ore, in order to be disposed of to the painters, and manufacturers of sealing wax, the rest is sorted into three parts, the first is the richest, and is in pieces of a moderate size, the second is in smaller pieces, and less abounding in metal, the third is the dust and smallest fragments of the other two, which are kneaded up with clay, and formed into bricks, that are dried carefully in the sun. The furnace used for extraction of the mercury is an oblong mass of masonry, divided horizontally into an upper and lower

compartment by an iron grate, and communicating near its top with a ſet of aludels. The charging of the furnace commences by laying on the grate a ſtratum of flat rough ſtones, leaving intervals between each for the paſſage of the fire: upon this is laid a bed of ore of the ſecond quality, then the ore of the firſt quality, afterwards another bed of the ſecond kind, and at the top of all a layer of the third kind made up into bricks. A few faggots are now thrown into the lower cavity of the furnace and lighted, which, in proportion as they are conſumed, are ſucceeded by others, and thus a gentle fire is kept up for 8 or 12 hours, according to the previous dryneſs of the ore. When the moiſture is got rid of, which is known by the ceſſation of the vapour, the fire-place is again filled with faggots, and, before theſe are conſumed, the maſs of ore will be ſufficiently heated to continue the combuſtion by means of the ſulphur that it contains without any additional fuel. During the next two days, as the ſulphur ſlowly burns away, the mercury, in the ſtate of vapour, paſſes into the aludels where it is condenſed; and at the end of this period, all the metal being extracted, the ſcoriæ are taken out of the furnace, and the aludels are emptied of their contents. Beſides the mercury, a conſiderable quantity of a black matter like ſoot is found in the aludels, which is readily ſeparated by ſpreading the whole about on an inclined table: the mercury runs to the lower end, where it is collected in a channel, while the impurities remain behind.

The conſumption of fuel and coſt of apparatus is conſiderably leſs than in the German method, but it is probable that a portion of mercury ſtill remains in the ore. A great loſs is alſo ſuſtained by throwing away the ſoot after ſeparating the running mercury on the tables, for not only many globules of the metal muſt eſcape notice, but alſo the calomel, cinnabar, &c. which it contains, are entirely waſted. This ſoot, previous to the ſeparation of the mercury, conſiſts, according to Prouſt[b], of

Mercury . .	66
Calomel . .	18
Cinnabar . .	1
Water & ſulphureous acid	2.5
Sulphat of ammonia	3.5
Lamp black .	5
Selenite . .	1
	97.0
Loſs	3.
	100.0

Hence the obvious way of turning it to moſt profit would be firſt to diſſolve out the ſulphat of ammonia, which might be diſpoſed of to great advantage to the ſal-ammoniac makers, then to mix the reſt with 12 or 15 per cent. of quicklime, and diſtill it in an iron retort, by which proceſs not only the whole of the running mercury would be driven over, but alſo that ariſing from the decompoſition of the calomel and cinnabar.

On account of the fluidity of mercury it cannot be conveyed from place to place without extraordinary precautions. The method of packing it is as follows. A freſh ſound ſheepſkin with the hair taken off is laid over a wooden bowl, and from 50 lbs. to 75 lbs. of mercury are poured into it; the ends of the ſkin are then gathered up, and tied together with great care, thus forming a ſort of bag in which the metal is incloſed; this bag is incloſed in a ſecond ſkin, and the ſecond in a third: laſtly, theſe bags are put into very tight barrels, capable of holding from two to four of them, and in this ſtate are brought into the market.

§. 3. *Phyſical and Chemical properties.*

Mercury is a metal always fluid at the temperature of our climates, of a white and perfectly reſplendent poliſhed ſurface, ſo as to reflect with extreme brilliance all objects, and is without ſmell or taſte in the metallic ſtate. Its ſpecific gravity is 13.56. Its expanſion by heat is on the whole very regular till a conſiderable diſtance above the point of boiling water, and hence its uſe in the conſtruction of *thermometers.* When expoſed to a cold of about —39 it ſolidifies, and when hard frozen it will bear gentle blows with a hammer, ſufficient to prove its malleability, though in ſo doing the friction ſoon heats it enough to make it reaſſume the liquid ſtate. Mercury boils at about 660°, and, if pure, totally evaporates without any reſiduum: but the vapour ſoon condenſes upon the adjacent bodies, coating them with a white dew, which is found by the microſcope to conſiſt of myriads of minute globules. When the galvanic fluid from a powerful apparatus is paſſed into mercury by immerſing the conducting wire into this fluid the mercury diſperſes in beautiful, brilliant, luminous ſtars, which ſeems to ſhew that this is a combuſtible metal.

Mercury is ſcarcely if at all changed by mere expoſure to air for any length of time, but if it be long agitated in any veſſel it is ſlowly reduced to a black duſt, ſoiling the fingers, which, however, on being heated, returns again to the ſtate of running mercury. Boerhaave was the firſt

[b] An. de Chim. iv. p. 226.

who performed this experiment by fastening a bottle half full of mercury to a mill wheel, and thus giving it a very long continued and violent shaking. The same has been done by fastening it to the wheel of a carriage during a long journey. Dr. Priestley[c] found this black powder to be formed in a variety of circumstances by a long agitation of mercury in phials with water, alcohol, &c. This powder heated gradually on an iron plate became of an uniform orange colour, and when digested in muriatic acid, it gave exactly the same appearances as the red oxyd, the precipitate per se. This black mercurial powder is stated by Fourcroy[d] to be composed of 96 parts of mercury and 4 of oxygen, though by others it is considered as mercury simply in a state of extreme division. Mercury is brought to the same state by being rubbed for some time with lard, gum arabic, honey, manna, vegetable extract, or any other clammy cohesive matter, which soon becomes black, or rather of a dark slate blue, by the divided metal. In this way mercury is constantly prepared for medicinal purposes.

Another and very important oxyd of mercury is made by keeping it nearly at its boiling point, and at the same time with sufficient access of air. This is generally performed in a very flat bottomed matrass with a tall neck, the mouth of which is unstopped, and which is set on a sand-heat, and kept there for many days. In this process as a certain renewal of the atmospheric air is required on the one hand, and on the other as the escape of the vapour of the boiling mercury should be prevented, it is rather difficult to contrive the best form of vessel for preparing it. If the neck be very narrow there is scarcely enough change of the air in contact with the mercury, so that on the whole it seems preferable to use a retort with the bottom flattened, and the neck only slightly bent, that the condensed globules of mercurial vapour may fall back into the vessel.[e] When the mercury has boiled for a few hours, a dull film forms on its surface, giving it the appearance of tarnished lead, and in about 48 hours after, small crystals of a dark brown or flea-coloured oxyd appear floating on the surface, which gradually increase till they form a friable crust over the whole of the metal. It is economical at this time to empty the retort, and separate the oxyd, which, when carefully collected, should be heated on an open pan in a heat just below visible redness, to dissipate the globules of uncalcined mercury which may be entangled within the crystals.

This brown oxyd is called *Calcined Mercury* or *Precipitate per se*, and is a perfectly pure oxyd of this metal of a dull ruby colour, and often regularly crystallized either in octohedrons or in lengthened four-sided pyramids. It consists, according to Lavoisier[f], of about 92 per cent. of mercury and 8 of oxygen. If this oxyd is kept some time gently heated with contact of air it becomes brown, and with a stronger heat (still below redness) it partly sublimes of a fine red. But when the heat is raised to redness the oxyd gradually disappears, oxygen gas of great purity is given out, and the metal returns to the reguline state, and may be collected in drops of running mercury. This experiment which from its simplicity is one of the most unexceptionable in support of the present theory of the oxydation of metals, was employed very early by Lavoisier, as will be mentioned under the article Oxygen.

When this oxyd is rubbed with running mercury[g] both substances lose their peculiar form, and the result is a black powder resembling in every respect the black oxyd procured from this metal by trituration, the red oxyd parting with a portion of its oxygen to the fresh mercury, and each being thereby converted to the black oxyd.

Another oxyd of this metal, very closely resembling the *precipitate per se*, is prepared by distilling nitric acid off this metal, which forms that beautiful red powder called *Red Precipitate*, or Red *Nitrous oxyd of mercury*. It is however not absolutely pure like the last, but always contains a very minute portion of nitric and of muriatic acid, and hence when reduced by distillation in a red heat, some azotic gas is given out, together with a little vapour of corrosive sublimate, owing to the muriatic acid from which the nitric acid is never absolutely free.

The oxygen gas from each oxyd also holds in solution a small portion of mercury in the state of vapour, which is gradually deposited, but is sufficient, when recent, to cause a salivation in the persons that frequently inhale it. The exact preparation of the red precipitate will be presently noticed.

Water either hot or cold has no ascertainable effect upon mercury, but if common mercury, which generally contains a little alloy of other metals, be boiled with water, the latter becomes

[c] On Air, vol. iii. p. 468. [d] Jour. des Mines, No. 70. [e] Higgin's Minutes. [f] Elements of Chemistry. [g] Fourcroy Systeme, tom. v.

turbid, acquires a metallic taste, and with it the power of destroying insects.

The salts produced by the union of mercury with the different acids have been more examined than those of perhaps any other metal, and require to be described somewhat at large. The Sulphuric acid has no action on mercury in the cold, but when heated, solution immediately begins, attended with a copious production of sulphureous acid vapour, which vapour received in water produces the liquid sulphureous acid in great purity, which is often prepared in this way. The mercury of course becomes oxygenated by the deoxygenation of the acid, and the oxyd dissolves in the remaining acid forming a sulphat of mercury. There are however as has been shewn by several chemists, and particularly by the accurate experiments of Fourcroy, several distinct salts and combinations of sulphuric acid and oxyd of mercury produced either by the proportions of the ingredients, or by the heat employed. Two parts of mercury to three of strong sulphuric acid are the proportions generally used. If the distillation of the acid from off the metal is stopped when the mixture has become a white saline mass, but before it is actually dry, the salt is very acrid and corrosive, with a strong excess of acid, and deliquesces if exposed to the air. In this state it is called by Fourcroy the *Acid Sulphat of Mercury*, or as we shall here term it the *super-sulphat of Mercury*. This salt may contain a variable proportion of acid, and it is more soluble in water as the quantity of acid is greater. On the average it requires about 155 parts of cold water and only 33 of boiling water, and gives an orange precipitate with the fixed alkalies. If this salt be washed with a much smaller quantity of cold water than is necessary to dissolve it, it loses a part of the mercurial oxyd together with the whole excess of acid, and if the washing be continued with small doses of water till the liquor ceases to turn blue vegetable colours red, and to give any proof of acidity, the salt that is left is found to be much changed in its nature. It is now white and not very acrid, requires for solution as much as 500 parts of cold, and about 250 of boiling water, and when crystallized from the hot saturated solution it appears in fine acicular prisms, which when dry, contain according to Fourcroy (the discoverer of this salt) 75 parts of mercury, 8 of oxygen, 12 of sulphuric acid, and 5 of water. The pure alkalies and lime-water also precipitate the metallic oxyd of a grey colour. In this salt the acid and metallic oxyd appear in a state of mutual saturation, and hence it should be termed simply *sulphat of mercury*. As it differs from the *super-sulphat* merely by losing the excess of acid, so it may readily be restored to that state by adding acid, and then its solubility in water proportionally increases, and it gives an orange precipitate by alkalies.

There is still another sulphat to be noticed. If the white saline mixture of sulphuric acid and mercury, or the super-sulphat above described, be urged still further in the fire in a heat considerably above that of boiling water, it parts with a still greater portion of acid, and becomes a dry hard grey mass.

If this be taken from the fire and boiling water poured on it, it immediately falls into a lemon-yellow powder, which, when well edulcorated with cold water, forms a well-known mercurial preparation, the *Turbith mineral*, or as Fourcroy names it, the *sulphat of mercury with excess of oxyd*, or in other words, the *sub-sulphat of mercury*. In making this preparation it is essential that all the excess of acid should be driven off by heat before the boiling water is added, otherwise the change of colour takes place very slowly and partially, and the water dissolves the remainder.

Turbith mineral approaches very nearly to the state of a simple oxyd; however it still retains a portion of acid, and hence, when heated strongly without addition, it gives out water and sulphureous acid gas, after which comes over a considerable quantity of oxygen gas, and lastly the reduced mercury distills over in its metallic form. Turbith also differs from both the super sulphat and simple sulphat of mercury, in being dissolved and decomposed by the nitric acid. It is likewise nearly insoluble in water, though, according to Fourcroy, a solution is effected by 2000 parts of cold water. When rubbed with running mercury the globules of the latter disappear, and the whole is changed to a black oxyd. A hundred parts of turbith contain 10 of sulphuric acid,[h] 76 of mercury, 11 of oxygen, and 3 of water.

The action of ammonia upon the sulphats, and on most of the other salts of mercury, is interesting and somewhat complicated. The experiments of Fourcroy have assisted materially in explaining this subject. When ammonia is added to a neutral salt of mercury (the sulphat for example) three separate actions take place:

[h] Fourcroy.

1ft. one portion of the alkali acts simply as an alkali in decomposing the salt by uniting with the acid and precipitating the metallic oxyd:—2dly, the precipitated oxyd is entirely decomposed by, and together with, another portion of the ammonia, the hydrogen of the ammonia, uniting with the oxygen of the metal, and reducing the latter to the metallic state, whilst the azot of the alkali escapes in the gaseous form: and 3dly, another portion of the ammonia unites with the entire salt without decomposition, forming a triple salt, the *ammoniaco-sulphat of mercury*. The reduced metal is in a state of extreme division, and is always of a dark blue or black colour, but by a magnifier the distinct globules of the metal may be seen. The black colour always assumed by almost all the salts of mercury, on adding ammonia, is therefore a proof of a partial reduction of the metal.

Hence when ammonia is poured into a solution of the *neutral* sulphat of mercury, a copious grey precipitate is deposited, which, exposed to the sun, is partly reduced to globules of mercury, whilst a grey powder remains. This grey powder is a triple salt, the ammoniaco-sulphat of mercury. If a great excess of ammonia is added, this salt is entirely redissolved, and the black reduced mercury is left pure. The same triple salt is formed by adding ammonia to the solid sulphat of mercury, which then effervesces strongly (owing to the escape of azotic gas) and the salt breaks to pieces with a snapping noise. If the liquor which holds the triple salt in solution by means of the excess of ammonia be evaporated gently, the excess is volatilized, and the triple salt is deposited, after some hours standing, in brilliant hard polygonal crystals. If, instead of waiting for this gradual crystallization, much cold water be added to the solution, it becomes at once milky, and the same salt is deposited, only differing from the former in being pulverulent instead of crystallized. If perfectly neutralized sulphat of ammonia be poured upon equally neutralized sulphat of mercury, a copious white precipitate is formed, which is the triple salt above-mentioned, and the supernatant liquor now contains a sensible excess of sulphuric acid, a very striking proof of the strong tendency of ammonia to unite with sulphat of mercury, since the affinity of the mercurial salt for the alkali, assisted by the consequent insolubility of the triple compound, is here sufficient to overcome the affinity of the alkali for the acid with which it was previously saturated.

The ammoniaco-mercurial sulphat has a pungent and styptic taste, is scarcely soluble in water, is partially (but not entirely) decomposed by lime and the fixed alkalies, and is composed of 18 per cent. of sulphuric acid, 33 of ammonia, and 10 of water, the remainder being oxyd of mercury. When heated to decomposition, it gives out ammonia, azotic gas, running mercury, and a little sulphite of ammonia.

The red and yellow oxyds of mercury are soluble in dilute sulphuric acid when heated, but without the evolution of sulphureous acid gas. When the solution is complete, it does not differ from those made with this acid and metallic mercury.

The liquid sulphureous acid has no action on reguline mercury. When poured on the red oxyd, the latter becomes immediately white, owing to a partial disoxygenation, since at the same time the acid loses its sulphureous smell. If much of the acid is added, and the mixture be exposed to the sun's rays, the oxyd is reduced even to the metallic state, and the liquor contains naked sulphuric acid.

The nitric acid dissolves mercury with great ease, with or without the assistance of heat, and various important combinations arise from the union of these substances. When mercury is put into cold nitric acid moderately diluted, a strong mutual action begins immediately, but as long as no heat is used, very little nitrous gas is given out. After standing some hours the acid becomes saturated, when it has dissolved about as much mercury as there was of concentrated acid employed. This solution is very heavy, clear, and colourless; it strongly corrodes animal and vegetable matters, and when evaporated it furnishes very heavy nearly transparent crystals of nitrated mercury, the form of which varies extremely, according to the heat and other circumstances of evaporation, but if this is performed slowly the crystals are often very large and beautiful, in the form of flattened truncated pyramids. As but little nitrous acid has been decomposed in making this solution (only a small quantity of nitrous gas having been given out) the metal is in a low state of oxygenation, and the solution mixes with water without any turbidness. In this state the pure fixed alkalies give a yellowish-white precipitate, and ammonia a greyish-black one.

But if (even with the same proportion of mercury to acid) a boiling heat has been used during the solution, nitrous gas is given out very copiously, and the solution when complete contains therefore the metal in a much higher state of oxydation than in the cold solution,

and a smaller relative proportion of acid. It is also much altered in its properties, for on dilution with water it lets fall a precipitate of a yellowish-white colour with cold, and orange-yellow with boiling water (nearly as the turbith is made with the sulphat of mercury,) which precipitate is composed of nitric acid with a great excess of mercurial oxyd, and may be called the *insoluble sub-nitrat of mercury*. The difference between these two solutions was first noticed by Bergman in his valuable Essay on the Analysis of Mineral Waters.[j] But when heat is used, the acid also becomes able to take up a much greater quantity of mercury, with this difference however, that if the solution be first made with heat, the disengagement of nitrous gas stops long before the acid is saturated, so that the latter portion of mercury does not appear to decompose any nitric acid in order to be dissolved, as Scheele has accurately observed. Nitric acid therefore, boiled on more mercury than it can dissolve, is supersaturated with mercurial oxyd, but as the last portion of mercury obtains no oxygen from the acid (otherwise nitrous gas would be given out) the question is whence it derives the oxygen necessary to its solution. This Berthollet rationally explains by supposing that the first dissolved portion, which when heat is used is left highly oxygenated, divides its oxygen with the last portion of mercury, so that the whole solution is equally oxygenated to a low degree. Hence it appears that there may be three saturated solutions of oxyd of mercury in nitric acid, each differing from the other, either in the respective proportions of metal and acid, or of oxygenation of the metal: namely, 1st, the solution made by saturating the acid with mercury without heat, which is the most acrid solution, crystallizes the most readily, and is not decomposable by water: 2dly, the same solution heated, by which the metal becomes more oxygenated, the acid is in somewhat smaller proportion, and the solution deposits the yellow nearly insoluble sub-nitrat by mere addition of water: and 3dly, the last-mentioned solution, supersaturated with mercury at a boiling heat, by which the acid becomes loaded with metal, which, for the reasons before-mentioned, is obviously less oxygenated than in the second case, and perhaps less than in the first also.

The crystallized nitrat of mercury, when kept in contact with air gradually changes, and from being nearly transparent and colourless, becomes covered at its surface with a yellow mealy substance, which is found to resemble exactly the yellow sub-nitrat separated from the solution made with heat, by the affusion of water. Hence it appears that the crystallized metal gradually absorbs oxygen from the air, and in so doing loses its ready solubility in water. An excess of nitric acid opposes this spontaneous change.

With ammonia effects are produced on the nitrat of mercury somewhat similar to those on the sulphat. If much of this alkali is added a copious black precipitate is produced, but if only in small quantity the precipitate is grey. This is an ammoniaco-mercurial nitrat scarcely soluble in water, mixed with a black mercurial powder, nearly reduced to the metallic state. The same grey precipitate is obtained by mixing nitrat of ammonia with nitrat of mercury. The solution yields by evaporation prismatic crystals, composed, according to Fourcroy, of 68.2 of oxyd of mercury, 16 of ammonia, and 15.8 of nitric acid and water.

When the crystallized nitrat of mercury is exposed to a heat gradually increasing, the first effect is to drive off the water; after which a thick red nitrous acid vapour arises, part of which is condensible by water, and the remainder is permanently elastic and flies off.

Dr. Higgins[k] found that on gradually distilling *per se* 34 ounces of dry white nitrat of mercury, about 8 ounces of acid and aqueous vapour were thus driven off, and nothing more would escape in a heat raised to about 600°. The residue is that red oxyd of mercury so generally known by the name of *Red precipitate*, or *Red nitrous oxyd of mercury*.

This oxyd is manufactured in the large way, being one of the most important of the mercurial preparations, and when very well made it is of a very beautiful uniform orange-red, and of a glistening scaly texture. Much technical nicety seems required to ensure this uniformly beautiful appearance, but the preparation of it for every useful purpose is not a matter of any great difficulty. The London Pharmacopœia gives the following recipe: mix in a glass vessel one pound of nitric acid, one pound of mercury, and one dram of muriatic acid, dissolve the mercury in the acid by help of a sand heat, then encrease the fire till the whole mass changes into red crystals, which are the red precipitate. The use of the muriatic acid here is supposed to be to assist in giving the beautiful colour. The whole process therefore consists essentially merely in dissolving the mercury in the acid, evaporating the solu-

[j] Essays, vol. i. p 133. [k] Minutes, &c. p. 40.

tion to dryneſs (it is not neceſſary to wait for a regular cryſtallization) and then to continue the heat with a cautious increaſe till every red vapour and every thing volatile is driven off. The heat may be raiſed almoſt to redneſs, but not beyond, otherwiſe the red oxyd itſelf is decompoſed. It ſeems preferable after the nitrat of mercury is thoroughly dry, to complete the expulſion of the nitrous vapour and converſion into red oxyd, by heating the ſaline maſs in a broad veſſel over an open fire rather than in a ſand-bath, great care being taken to avoid breathing the fumes of the acid, which ſeem to carry away a ſmall portion of the metal, and are very noxious. As the nitrous acid here uſed generally contains a ſmall portion of muriatic acid, ſome corroſive ſublimate is alſo formed and volatilized in the drying, which much contributes to the noxious quality of the vapour.

In the proportions above given equal parts of mercury and acid are taken, but this is more acid than is neceſſary, ſince a portion of undecompoſed nitrous acid is expelled during the drying. Fiſcher [1] aſſerts that in the common way of preparing this ſalt by heating the white cryſtallized nitrat, the acid is ſo far from being ſaturated that perfectly good precipitate may be made by rubbing this cryſtallized ſalt with its own weight of running mercury, (which thoroughly mixes with it in a very few minutes) and then heating as uſual till the whole becomes an uniform red maſs.

By this method a large portion of the acid is ſaved, but we cannot help doubting the perfect accuracy of the experiment. No harm, however, can ariſe from the uſe of an exceſs of nitric acid, ſince all the ſuperfluous part is loſt in the evaporation, and therefore on the whole it ſeems the beſt not to load the acid with much more than its own weight of the metal.

Red precipitate, well prepared, ſo cloſely reſembles the *precipitate per ſe*, or oxyd formed by ſimple calcination, already deſcribed, that there is little danger of error in adopting the uſual opinion that they are identically the ſame and are compoſed only of mercury and oxygen. The phenomena of their decompoſition too moſt cloſely correſpond, for when the red nitrous oxyd is heated to redneſs it gives out a copious ſtream of oxygen, and the metal diſtills over in its reguline ſtate, leaving at laſt not an atom of any ſubſtance in the diſtilling veſſel. The only known difference between the two (colour excepted, which is much the brighteſt in the red nitrous oxyd) is that the nitrous oxyd gives out, beſides oxygen, a certain portion of azotic gas, owing to the final decompoſition of the laſt adhering particles of nitrous acid.

The oxygen gas from this as from the other mercurial oxyds is always at firſt mixed with ſome mercury in vapour, and ſometimes with a minute portion of corroſive ſublimate, ſo that it is not fit for all the purpoſes of oxygen gas till it has ſtood for ſeveral hours in contact with water.

Nitrat of mercury in every ſtate of oxygenation is readily decompoſed by many other acids. If ſulphuric acid or any alkaline ſulphat be poured into liquid nitrat of mercury, a white precipitate is produced, which by waſhing becomes yellow, and is the ſub-ſulphat or turbith. If muriatic acid or any alkaline muriat is added, the precipitate is a white muriat, but under certain limitations which will be preſently mentioned.

There are two (and only two) combinations of mercury with the muriatic acid, forming ſalts of very different properties in every reſpect, both of which are of high importance in technical as well as experimental chemiſtry, and have engaged more of the attention of chemiſts than perhaps any other of the metallic ſalts. One of theſe is a very ſoluble cryſtallizable ſalt of a very acrid nauſeous taſte and a violent poiſon in any but ſmall doſes, which is prepared almoſt entirely by ſublimation, and is called *corroſive ſublimate*, or *corroſive muriat of mercury*, or at preſent by ſome, ſimply *muriat of mercury*, and by ſeveral of the French chemiſts, though incorrectly, *oxymuriat of mercury*. This ſalt conſiſts of muriatic acid and mercury oxydated to a high degree.

The other combination of mercury with the marine acid is a white powder with but little taſte, inſoluble in water, and prepared ſometimes by ſublimation, (by which method alone it is cryſtallizable) ſometimes in the moiſt way. It conſiſts of muriatic acid ſuperſaturated with mercury at a lower ſtate of oxydation than in the former ſalt, and may be prepared (as it often actually is) by combining the corroſive muriat with an additional portion of mercury in the metallic ſtate, whereby the ſame relative portion of acid is united with much more metal, and the oxygen of the ſalt diſtributes itſelf equally to the newly-added mercury, bringing the whole to a lower ſtate of oxydation. This latter preparation has received the various names of *mild mercurial muriat*, or

[1] Scherer's Journal, or Phil. Mag. vol. xvii.

sweet mercury (being much less active in its effects on the animal body than the former) and also *calomel*, by which name it is most known in medicine. To avoid confusion we shall at present chiefly employ the terms *corrosive muriat*, and *calomel*, in describing these different salts.

Mercury in the metallic state is not acted on by the muriatic acid, either hot or cold, but when the metal is previously oxydated or dissolved in an acid, the muriatic acid readily unites with it, and it is in this indirect way that the muriats of mercury are formed.

Corrosive muriat is prepared almost exclusively by the process of sublimation. All the materials necessary are; mercury, brought to a high degree of oxydation by previous solution in an acid; and muriatic acid in a state fit to be disengaged in the vaporous form; and the heat used for subliming expels both the mercury and the acid in union with each other, which on cooling crystallize into the corrosive salt.

One good method therefore of making this salt (which is often used) is the following. Dissolve in a glass vessel [m] 8 ounces of mercury in 10 or 12 ounces of nitric acid, evaporate this solution to perfect dryness, which leaves a white salt, the nitrat of mercury; rub this salt in a mortar not made of metal with 8 ounces of decrepitated common salt, and as much sulphat of iron previously dried to a white powder by heat. When these materials are well mixed, put them into a matrass, of which two-thirds are left empty, place it on a sand-bath with the hot sand just hiding the materials, and proceed to sublimation with a heat gradually raised to redness, allowing the fumes to pass off up a chimney, as they would be dangerous to breathe. When cold, break the matrass carefully (which is better done if it is previously cracked round with a cold wet iron while still hot) and separate the white crystallized sublimate from what remains at the bottom. The former is the corrosive muriat, the latter is a mixture of sulphat of soda and oxyd of iron arising from the mutual decomposition of the common salt and the sulphat of iron. The sole use of the sulphat of iron is to afford sulphuric acid, in order to disengage the acid of the common salt in a vaporous form. The corrosive sublimate formed in this operation is beautifully crystallized in needles if the heat be moderate, but if it be too great, the salt coalesces into a single cake composed of very small crystalline particles.

In some of the large manufactories of this salt in Holland, the mercury is said not to be previously dissolved in nitrous acid but simply ground to fine powder along with the salt and vitriol of iron.

Whenever sulphat of iron is employed, the sublimate is liable to be contaminated with a portion of oxyd of iron, this metal being to the full as volatilizable by muriatic acid as the oxyd of mercury is, but the following simple and excellent process first invented by Kunkel [n] excludes iron altogether.

Take equal weights of mercury and sulphuric acid, distill the mixture to dryness till only the white sulphat of mercury is left, mix this latter salt with about its own weight of common salt, rubbing the mixture well, and then sublime in the way before mentioned. The sublimate is very pure corrosive muriat of mercury, and the residue at the bottom of the vessel is sulphat of soda. The London Pharmacopœia has adopted this method: the proportions employed are two pounds of mercury, as much sulphuric acid, and three pounds and a half of common salt. In preparing the sulphat of mercury for this process, the heating of the acid and the mercury must not be carried so far as to drive off any of the acid which properly belongs to the sulphat of mercury, or in other words, the mixture must not be reduced to the state of turbith, otherwise there will be no sulphuric acid left to expel the muriatic acid from the common salt. But if turbith be employed some fresh sulphuric acid must be added.

Another method nearly as economical as the former, is to grind up mercury, sulphat of iron, common salt, and nitre, and then sublime. Here both the nitrous and muriatic acids are driven from their bases by the superior affinity of the sulphuric, and the mercury, first dissolved by the nitrous acid, is afterwards united to the muriatic in the form of corrosive muriat when sublimed.

A sulphat of mercury fit for giving corrosive muriat by sublimation with common salt is also formed very expeditiously by adding nitrated mercury to a solution of sulphat of potash, when a white salt, the sub-sulphat of mercury, is precipitated, being very little soluble, and the clear liquor consists chiefly of nitrat of potash formed by double affinity.

With regard to the actual quantity of sublimate produced from a given proportion of materials, it has been found by an eminent practical chemist [o] that 16 ounces of mercury with 15 ounces of strong sulphuric acid (which is sufficient) will yield about 23¼ ounces of dry

[m] Beaumé. [n] Bergman's Essays, vol. iii. [o] Original communication.

ſulphat of mercury, which, ſublimed with 30 oz. of dried muriat of ſoda, yield 20 oz. of corroſive muriat.

Corroſive muriat may be prepared without ſublimation: the uſe of this latter proceſs being only to ſeparate the ſalt from the other materials which are not volatile at a low red heat. The following way is given by Von Schmidt:[p] diſſolve 2 ounces of mercury in $3\frac{1}{2}$ oz. (a leſs quantity would be ſufficient) of ſulphuric acid, and diſtil to dryneſs in the uſual way. Add to the white ſulphat of mercury in the retort a ſolution of $5\frac{1}{2}$ oz. of common ſalt, and boil the mixture for an hour, then filter the liquor while hot, and evaporate it to dryneſs. Add to the reſiduum (which now conſiſts of ſulphat of ſoda, corroſive muriat, and perhaps ſome undecompoſed common ſalt) about 16 oz. of alcohol, digeſt for an hour in a moderate warmth, and decant off the clear liquid. This is a ſolution of the corroſive muriat in the alcohol, the other ſalts being inſoluble in the ſpirit, and therefore remaining at the bottom. Then evaporate the alcoholic ſolution to dryneſs, which leaves the corroſive muriat as a perfectly white maſs which may be obtained in beautiful cryſtals by ſubſequent diſſolution in boiling water and cooling. To extract all the mercurial muriat from the maſs it will be adviſeable to repeat the proceſs with about 8 oz. more of alcohol, and proceed as before.

Corroſive muriat may alſo be made by direct ſolution and cryſtallization. If oxyd of mercury is mixed with water in a Woulfe's bottle, and a current of oxymuriatic acid gas be paſſed through for ſome time, a ſolution is formed, which gives by evaporation cryſtals of very pure corroſive muriat. In this manner the ſalt may be obtained of perfect purity.

The ſame product is formed when oxymuriatic acid is added to the nitrat of mercury either ſoluble or inſoluble in water; by evaporation the nitric acid flies off, together with the exceſs of oxymuriatic acid, and the corroſive muriat is obtained in very pure and regular cryſtals.

But if oxymuriatic acid be poured on running mercury it firſt reduces it to a grey powder without extrication of any gas, which powder is the ſame in nature as the mild muriat or calomel to be preſently deſcribed. But if an exceſs of the acid be ſo uſed this grey powder is diſſolved, and the ſolution is changed to corroſive muriat.

Corroſive muriat, in whatever way it be formed, is a ſalt which cryſtallizes, when formed by ſublimation, generally in long needles, but by watery ſolution it affects the form of four-ſided priſms. Its taſte is extremely acrid, nauſeous, and ſtrongly metallic, and ſo permanent that it is very difficult to get it off the palate. It is not deliqueſcent. Cold water diſſolves $\frac{1}{16}$ to $\frac{1}{20}$ of its weight of this ſalt, but boiling water much more. When heated moderately (but to a degree much above that of boiling water) it ſublimes in the form of a denſe white ſmoke moſt exceſſively prejudicial to thoſe that reſpire it. Light has a powerful effect on this ſalt. If it is expoſed to a ſtrong light it after a while becomes mealy on the ſurface, and if then thrown into boiling water the whole will not diſſolve as at firſt, but a reſidue of a dingy white colour ſettles to the bottom which is found to be calomel. Alſo when a clear ſolution of the ſalt is expoſed to the ſun's rays a ſimilar precipitation of a white inſoluble ſubmuriat takes place. Hence all ſolutions of this ſalt becomes muddy by keeping unleſs ſecluded from the light. M. Boulley[q] found that during this change oxygen was given out.

This ſalt is alſo ſoluble in alcohol, which when moderately warm takes up about $\frac{1}{6}$ of its weight.[r] Boiling alcohol diſſolves nearly its own weight, moſt of which ſeparates again on cooling.

Sulphuric acid[s] does not decompoſe this ſalt, but being poured on it, reduces it to a powder, ſimply owing to the abſtraction of its water of cryſtallization; for on adding water the powder is entirely rediſſolved. Nitrous acid added to this ſalt diſſolves it when heated and lets it go on cooling, unaltered. The muriatic acid diſſolves this ſalt, but renders it leſs eaſily cryſtallizable.

All the alkalies and alkaline earths decompoſe corroſive ſublimate. The fixed alkalies and alkaline earths when cauſtic give a precipitate, at firſt orange, which afterwards deepens into a brick red. But the carbonated alkalies produce a precipitate of a much lighter ſhade of colour. Corroſive muriat and alkalies therefore are mutually a teſt for each other, and are often uſed as ſuch.

The action of ammonia on this ſalt is ſingular. With the other ſolutions of mercury ammonia gives a black powder, which is the metal almoſt reduced to a metallic ſtate, as already mentioned, but when this alkali is added to a ſolution of corroſive muriat a copious *white precipitate* falls down, which remains white after

[p] Van. Mons Journ. or Phil. Mag. Vol. xvi. [q] Ann. de Chem. tom. lxiv. [r] Eſſays Vol. iii. [s] Bergman.

deficcation. Fourcroy found that 100 parts of the muriat superfaturated with ammonia gave 86 parts of white precipitate, whereas cauftic foda gave only 75 of brick-red oxyd. The white precipitate therefore contains fomething befides oxyd of mercury. It was infoluble in water, and when diftilled per fe in a retort it gave out ammonia, azotic gas, and 86 per cent. of calomel was left. By further analyfis Fourcroy found this white precipitate to confift of 81 of oxyd of mercury, 16 of muriatic acid, and 3 of ammonia. It is therefore a triple compound, but rendered infoluble by the great excefs of mercury. Sulphuric acid converts it to corrofive muriat and ammoniaco-fulphat of mercury. Muriatic acid rediffolves this precipitate, and produces the fame falt as is formed by the addition of muriat of ammonia to corrofive muriat, and which is of a very peculiar nature.

When mercury, muriatic acid, and ammonia are in a ftate of mutual faturation without decompofition, (as happens when muriat of ammonia is added to corrofive muriat) a moft intimate combination takes place between the three fubftances, and the mercurial muriat by help of the fal ammoniac is rendered full twenty times more foluble in water than before, for one part of fal ammoniac diffolved in 3 of water, will enable the latter to diffolve no lefs than 5 parts of the mercurial falt when the temperature is raifed. This triple combination is not broken by fublimation, for the falt that rifes in this procefs ftill contains ammonia and is equally refoluble in a fmall proportion of water. This triple falt, long known to the older chemifts was called by them *Sal alembroth*. In modern nomenclature it is termed *the ammoniaco-mercurial muriat*.

If to the folution of this falt (formed by equal weights of muriated ammonia and corrofive muriat) be added a carbonated fixed alkali, an effervefcence takes place, and a white precipitate is formed, fimilar to that produced by fuperfaturating corrofive muriat with ammonia, which, as already mentioned, ftill confifts of muriatic acid, ammonia, and oxyd of mercury, but the latter fo much in excefs as to be rendered infoluble. This is the common *white precipitate* of pharmacy, which muft be carefully diftinguifhed from the fimple fub-muriat or calomel. If however too much fixed alkali be added, the precipitate is yellow. Eight parts of corrofive muriat will yield about 7¼ of white precipitate.

The exact compofition of corrofive muriat will be mentioned after defcribing the mild muriat or calomel.

Corrofive muriat is one of the moft active mercurial medicines, and is one of the moft violent poifons in an over-dofe, of all the metallic falts, inflaming and diforganizing the whole alimentary canal. But it preferves dead animal matter very perfectly, which when wafhed with a faturated folution of the falt and expofed to the air is foon covered with a faline cruft or varnifh which no infect can touch.

The next combination of mercury with muriatic acid to be mentioned, is the *Sub-muriat, mild or fweet Muriat, or Calomel*. It differs from corrofive fublimate not in the number and nature of its conftituent parts but only in their proportion, and is found by numerous experiments to contain in equal weights more mercury, or, (what is the fame thing) lefs acid, and the mercury lefs oxydated. Thefe two circumftances will explain the many cafes of the mutual converfion of the one falt into the other, and production of one from the other by various chemical agents.

The fub-muriat is made in two ways, either by precipitation from folution, or by fublimation. The latter is the moft antient, and is thus performed. Take one pound of corrofive fublimate and nine ounces of running mercury, rub them in a mortar with juft water enough to prevent the fublimate from flying off in duft till the whole becomes a grey powder, and no globules of mercury can any longer be perceived. Put this powder into one or more glafs fubliming veffels (common phials will anfwer in the fmall way, which fhould be no more than half full) and fet them on a fand bath covered up to the beginning of the neck with the hot fand, and fublime with a heat gradually increafed. The firft fubliming of the calomel is perceived by a white vapour which iffues from the mouth of the veffel. The calomel is not pure after the firft operation, for a fmall portion of undecompofed mercury and of corrofive fublimate firft rife and occupy the top of the veffel. Below this is a white cake, which is the true fub-muriat, and at the bottom of the veffel remains a fmall quantity of reddifh oxyd which cannot be fublimed. The whole contents of the fubliming veffel are then to be rubbed together and again fubmitted to the fame procefs, and when finifhed the cake of calomel which occupies the middle of the veffel is to be carefully feparated and wafhed repeatedly with hot water to free it from any adhering particles of corrofive fublimate.

Some chemists have thought proper to repeat the sublimation of calomel for five, six, or more times (separating after each time the white powder that rises first and fixes to the top of the bottles) with a view of more compleatly combining the sublimate with the mercury and rendering it a more uniform and safer medicine. But it is clearly shewn that no good whatever can arise from such frequent sublimation, but on the contrary, the calomel every time becomes in some degree decomposed and its properties injured.

Calomel nine times sublimed forms what has been called by some the *Mercurial Panacea*.

The sub-muriat of mercury is a white solid mass sometimes crystallized in tetrahedral prisms when slowly sublimed. It differs most essentially from corrosive sublimate in many sensible and chemical properties. It is nearly, if not entirely insoluble in water, it has but little taste, but what there is is metallic and nauseous, it becomes yellowish by long exposure to light and is luminous when rubbed in the dark. It requires a greater heat to be sublimed than the corrosive muriat does, whence after sublimation of a mixture of the two, the upper portion is chiefly the corrosive muriat and the lower part is the calomel. When lime-water or the alkalies are added to calomel it immediately blackens, which circumstance is a very useful test for this substance.

The sub-muriat may also be prepared in the moist way and without sublimation by adding nitrat of mercury to muriat of soda. A double decomposition takes place here, the muriatic acid uniting with the mercury into the sub-muriat (which being insoluble in water falls to the bottom) and the nitric acid and soda of the salt remain united in the liquor. For this process we are indebted to the illustrious Scheele, whence the preparation is sometimes called Scheele's Calomel. It is thus made. Take a solution of mercury in nitrous acid so strong as to be perfectly saturated even while boiling. For this about six ounces of acid, and as much mercury may be used. Then pour the solution rather gradually into another vessel containing four ounces of common salt dissolved in half a pint of boiling water.

When the white sub-muriat has entirely subsided, pour off the supernatant liquor and wash the precipitate thoroughly with warm water, then dry it in a gentle heat.

The sub-muriat prepared in this way scarcely if at all differs from the calomel formed by sublimation, being equally insoluble in water, blackened by lime-water, and shewing all the other properties of calomel. This precaution however is to be observed, which is, that as the nitrous solution when loaded with mercury (as in the present case) is in part decomposable by mere water, it should be dropped gradually into the solution of salt with frequent stirring, (and not the salt added to the nitrat as directed by some) and also, as Mr. Chenevix has observed, it will more entirely secure the decomposition of the nitrat if a little muriatic acid be added to the solution of common salt before it is used. The sub-muriat thus prepared may also if necessary be afterwards sublimed, and it will be found to rise in the subliming vessel almost without any residue.

Mercury is not known to exist in any other form of combination with muriatic acid than as corrosive muriat and sub-muriat, no intermediate state of saturation with the acid having been ever observed, and as before mentioned, the difference between the two salts is, that the corrosive muriat contains more acid than the sub-muriat, less mercury, and the mercury is in a lower state of oxygenation. A number of facts have been observed by chemists relating to the mutual change of one of these salts into the other by different reagents some of which may be mentioned.

Beaumé endeavoured to form some intermediate muriat of mercury both by mixing and subliming proportions of corrosive sublimate and running mercury, different from those that constitute calomel, and by mixing corrosive muriat and calomel and subliming, but in no instance was there produced any thing but corrosive muriat and calomel.

The proportion of sub-muriat produced in Scheele's method depends on the degree in which the nitric acid is saturated with the mercury. If an excess of acid remains, but little calomel is produced on adding the common salt, and the solution contains corrosive muriat.

The mercury in calomel is less oxygenated than in corrosive muriat, and many curious experiments have been made illustrating this fact. Thus, as Proust observes, if muriatic acid be boiled on calomel, corrosive muriat is formed, and some running mercury appears, so that the calomel is divided into two portions, one of which takes the oxygen belonging to both and unites with the acid into corrosive muriat, and the other therefore is reduced to the metallic state.

Lussac found that on mixing corrosive sublimate and red oxyd of mercury, and subliming,

if the heat was moderate the corrosive muriat rose in the vessel unaltered, but at a low red heat, calomel was produced. Now as the red oxyd parts with its oxygen at this heat, the remaining mercury must have been reduced to the metallic state, and thus by combining with the corrosive muriat produced the calomel.

The precipitate from nitrat of mercury by potash or soda gives no calomel when combined with corrosive muriat and sublimed at a moderate heat, as Cornette has observed:[p] but when the precipitate from nitrated mercury by *ammonia* is used, a large quantity of perfect calomel is procured.

This experiment, Cornette very satisfactorily explains by shewing the different nature of the precipitate by ammonia from those by the fixed alkalies, and the property of the volatile alkali to reduce metallic oxyds to their reguline state.

The deoxydating power of muriat of tin shews in a satisfactory way the respective composition of corrosive muriat and calomel.

Muriat of tin (as will be mentioned under that article) when saturated with metal has the power of depriving mercurial solutions of their oxygen and reducing them to the metallic state.

When *a few drops* of muriat of tin[q] are added to a solution of corrosive muriat, a whitish yellow powder is obtained which agrees in every property with calomel; if a little more of the tin is added, the powder becomes grey, and on examination by the microscope is found to be globules of running mercury. But if a large quantity of muriat of tin is added at once to the corrosive muriat, the intermediate state of calomel is not produced, and the mercury at once assumes the reguline form.

When nitrous acid is added to calomel, a copious disengagement of nitrous fumes takes place, (which does not happen with the perfect oxyds of mercury) the calomel is dissolved, and the solution distilled to dryness gives a white saline mass. This, heated in a close vessel gives about half its weight of a crystallized salt which sublimes at the upper part of the vessel and is corrosive muriat. The remainder when further heated, emits abundant red fumes, changes colour, and at last is converted into the red oxyd of mercury.

It has been supposed by some chemists of eminence, that the acid of corrosive sublimate was the oxy-muriatic, or in other words, that a part of the oxygen which is contained in this salt is united to the acid and not to the mercury. As long as they are actually in combination it is not easy (if at all possible) to make this distinction, but it is certain that whenever the acid is separated from the salt it appears in the form of the simple muriatic, and not the oxy-muriatic. Mr. Chenevix's experiments[r] on this head are decisive, as will be further mentioned under the article *Oxymuriatic Acid*. When the sulphuric acid is added to corrosive muriat, no acid fumes are disengaged, whereas if the acid were the oxymuriatic, it would probably be set at liberty. Likewise when corrosive muriat is decomposed by potash, the result is simply oxyd of mercury and *muriat* of potash, not *oxymuriat*. Nitrat of silver also gives a precipitate of simple muriat of silver or luna cornea.

To determine the composition of corrosive muriat and of calomel, Mr. Chenevix first decomposed 100 grains of corrosive muriat by nitrat of silver to estimate the muriatic acid, and another 100 grains by potash for the oxyd of mercury, and thus found the constituents of corrosive muriat to be 82 per cent. of oxyd of mercury, and 18 of muriatic acid. To find out the degree of oxygenation of the metal, another portion of mercury was dissolved in nitric acid, to which was added muriatic acid, and the whole was then evaporated to dryness, and sublimed. A hundred grains of mercury thus treated gave 143.5 of corrosive sublimate, whence (the quantity of acid in this salt being previously known) the respective quantities of mercury and oxygen were ascertained, and it appears that the metal is here oxydated at the rate of 15 of oxygen in 100 of oxyd. Calomel was then treated in a similar way, being first dissolved in nitric acid and decomposed by nitrat of silver to determine the quantity of muriatic acid, whence it was found to consist of 88.5 of oxyd of mercury, and 11.5 of muriatic acid. To find the state of oxydation in calomel, a given portion was boiled with nitro-muriatic acid, evaporated to dryness, and sublimed, by which it was totally converted into corrosive muriat, and, by comparing these data with known proportions of the corrosive muriat before ascertained, Mr. C. found the metal in calomel to be oxydated at the rate of only 10.7 of oxygen in 100 of oxyd, whereas that of corrosive muriat is 15 in 100.

[p] Mem. de l'Acad. for 1786.

[q] Proust J. Phys. Tom. 59. p. 337.

[r] Phil. Trans. for 1802.

A hundred parts of calomel therefore contain

Mercury	79	88.5
Oxygen	9.5	
Muriatic acid		11.5
		100.0

A hundred parts of corroſive muriat contain

Mercury	69.7	82
Oxygen	12.3	
Muriatic acid		18
		100.

Mr. Chenevix in aſcertaining that corroſive ſublimate was not oxymuriat of mercury, but merely muriat of mercury highly oxydated, has diſcovered a ſalt which is truly the oxymuriat of this metal. By paſſing a current of oxymuriatic gas through water in which there was ſome red oxyd of mercury, after a time the red oxyd became of a very dark brown colour, and part of it was diſſolved. The liquor was then evaporated nearly to dryneſs and a mixed ſalt was obtained, conſiſting partly of corroſive muriat, and partly of another ſalt which cryſtallized later than the former, and on being rediſſolved and cryſtallized appeared nearly pure. This ſalt has not been much examined, but it poſſeſſes the eſſential quality of an oxymuriat in giving out vapours of oxymuriatic acid by the affuſion of the ſulphuric or any ſtronger acid.

The action of moſt of the other acids on mercury has been examined, but few of the ſalts are intereſting.

The acetous acid has no action on mercury, but if boiled on its oxyds it diſſolves them, though with difficulty. But the beſt and moſt effectual way of making the acetited mercury is by the double decompoſition of nitrated mercury and acetited potaſh. For this purpoſe take 3 ounces of mercury,[f] diſſolve it in about $4\frac{1}{2}$ oz. of nitric acid or a little more than is ſufficient for ſolution without heat. Mix this with 3 oz. of acetite of potaſh previouſly diſſolved in 8 pounds of boiling water and ſet the whole aſide to cryſtallize, which takes place as the liquor cools, and the acetited mercury then ſeparates in the form of fine ſoft micaceous cryſtalline plates, very light and ſpungy. Then waſh them with cold water and dry them by paſſing between folds of blotting paper.

In preparing this ſalt it is eſſential to pour the mercurial ſolution into the acetite, otherwiſe part of the nitrat of mercury would be decompoſed by the mere water of the ſolution, and an inſoluble ſub-nitrat would be mixed with the acetite. The quantity of water of ſolution here directed is ſufficient to diſſolve, when boiling, both the acetite of mercury and the nitrat of potaſh; but the proceſs ſucceeds as well if only a few ounces of water are uſed, ſufficient to diſſolve the new formed nitrat of potaſh, in which caſe the whole acetite of mercury is precipitated and may be ſeparated and ſubſequently rediſſolved and cryſtallized. Neither is it neceſſary to uſe the cryſtallized acetite of potaſh, diſtilled vinegar nearly ſaturated with potaſh anſwering all the purpoſe.

Acetited mercury is ſcarcely ſoluble in cold water, but readily diſſolves as the heat is raiſed. The dry ſalt is eaſily decompoſed by heat.

The carbonic acid only unites with mercury when an acid ſolution is precipitated by a carbonated alkali. The carbonated oxyds are white and remain ſo unaltered by the air.

The boracic acid may be made to unite with mercury in the ſame way as the acetous acid, that is by double decompoſition. For this purpoſe common borax muſt firſt be neutralized with its own acid, then diſſolved in water, and nitrated mercury poured into it. The borat of mercury partly ſeparates on the firſt mixture of the liquor, and more may be obtained by evaporation. This ſalt is in the form of brilliant ſcales, which grow yellow by expoſure to air.

The phoſphat of mercury is formed in the ſame way as the laſt, by adding nitrat of mercury to an alkaline phoſphat. A white precipitate is formed which is phoſphat of mercury nearly inſoluble.

When the nitrat of mercury is decompoſed by alcohol, a very ſingular powder is produced, which appears to be the oxalat of this metal, and poſſeſſes a moſt aſtoniſhing power of exploſion when kindled, as diſcovered by Mr. Howard. This fulminating mercury will be deſcribed in the next article.

None of the alkalies have any action upon mercury, but the fixed alkalies diſſolve its oxyds. Theſe combinations have been but little examined.

Ammonia added to any of the mercurial oxyds immediately blackens them, cauſes the diſengagement of azotic gas, and reduces them nearly to the metallic ſtate. Fourcroy alſo aſſerts that another action takes place, namely, the production of a quantity of nitric acid by

[f] Pharm. Edinb.

means of part of the azot of the decompoſed ammonia, which acid, as ſoon as formed, ſeizes on part of the ammonia and part of the mercury, producing the ammoniaco-mercurial nitrat already deſcribed.

Mercury is capable of combining with ſulphur under various circumſtances and in different proportions; and as the rationale of theſe proceſſes has excited no ſmall controverſy among ſome of the ableſt modern chemiſts, we ſhall endeavour to give a clear and full ſtatement both of the facts and opinions belonging to this intereſting ſubject.

If one part of mercury and three parts of flowers of ſulphur are triturated together in a mortar, the globules of metal by degrees diſappear and combine with the ſulphur into a dark grey powder, which becomes more and more deep coloured the longer the trituration is continued. When the ingredients are ſo accurately ground together that no more globules of mercury can be diſtinguiſhed by the naked eye, mere expoſure to the air without any further trituration will at length render the powder perfectly black: in this ſtate it was known to ancient chemiſts by the name of *Ethiops mineral.* This ſubſtance, from its colour and from its becoming more and more black by expoſure to the air, is ſuppoſed by Fourcroy and certain other modern chemiſts, to be a compound of ſulphur and black oxyd of mercury. But this opinion ſeems to be entirely deſtitute of foundation; for if the ſulphur and mercury in the requiſite proportions be put into a dry vial and cloſely corked, and afterwards ſhaken vigorouſly for about a quarter of an hour, a perfectly black ethiops will be produced, and yet the incloſed air upon examination will be found to be neither altered in bulk nor deprived of any oxygen. The mercury and ſulphur in this ethiops are ſuppoſed to be much more looſely combined than in the ethiops made by heat, becauſe if the former is rubbed upon gold it will whiten its ſurface, which the latter is incapable of doing; this effect however may well happen from the minute uncombined globules of metal with which the ethiops generally abounds, rather than from the actual decompoſition of that portion which has united with the ſulphur.

But although mercury and ſulphur are capable of uniting with each other at the uſual atmoſpheric temperature, yet the combination takes place much more rapidly, and a ſmaller proportion of ſulphur is neceſſary for the ſaturation of the mercury, if both the ingredients are preſented to each other in a liquid ſtate. For this purpoſe let any quantity of ſulphur be melted in an earthen pot, and an equal weight of mercury be then added, care being taken to mix the two ſubſtances by accurately ſtirring them with a tobacco-pipe, or any other convenient inſtrument; an immediate combination will then take place, the maſs will become black and hot even to inflammation, (which however muſt be extinguiſhed as ſpeedily as poſſible, leſt a loſs both of ſulphur and metal be ſuſtained). When no more globules of mercury are perceptible let the veſſel be removed from the fire and its contents allowed to cool, ſtirring them all the while. The reſulting compound is in the form of ſmall hard black lumps, and is called *Ethiops mineral prepared by fire.* It differs from the preceding in containing leſs ſulphur, and when rubbed upon gold, does not whiten it, probably on account of its holding no uncombined mercury.

There is a third ſpecies of ethiops mineral prepared like the preceding by fuſion, but differing materially in the proportion of its ingredients; for, whereas the former contains equal parts of ſulphur and mercury; in this the ſulphur does not exceed 20 per cent. of the whole maſs. In conſequence of this exceſs of mercury, more time and a higher heat are required to accompliſh the combination, and it is attended by a remarkable evolution of flame at the moment of combination, that renders it unſafe to make uſe of cloſe veſſels for this purpoſe. Beaumé[t] relates, as the reſult of his own experiments, that the common ethiops may be prepared at the loweſt heat at which ſulphur becomes fluid, and that the combination takes place in perfect quiet: but when the materials are employed in the proportion of the latter mentioned ethiops, a conſiderable part of the mercury will remain uncombined, except at a temperature equal to that in which ſulphur becomes glutinous: while the union is taking place the maſs heats ſpontaneouſly, and a jet of flame is diſengaged. The colour of this ethiops is a dark violet; and by ſublimation at a red heat it becomes of a browniſh blood colour when in maſs, but when levigated it exhibits a bright crimſon, verging more or leſs upon ſcarlet. In this ſtate it is called cinnabar or vermillion, and probably differs in nothing but its ſuperior purity from the native cinnabar.

The prepared cinnabar being much preferable to the native as a pigment, has long been a conſiderable article of chemical manufacture, and as the Dutch have the reputation of making the

[t] Chem. Experiment. ii. p. 459.

best, we shall here describe their method of proceeding, as related by M. Tuckert.[u] This manufacture consists of two distinct operations, the one being the preparation of the ethiops, the other the conversion of the ethiops into cinnabar. To make the ethiops, a boiler of iron polished on the inside, and about 2½ feet in diameter, and 1 in depth, is charged with 1080 lbs of mercury, and 150 lbs of sulphur (or *per cent.* 87.8 mercury, and 12.2 sulphur) a moderate heat is then applied gradually increasing, and accompanied by suitable stirring of the ingredients till the whole appears to be thoroughly mixed and combined. The black sulphuret of mercury thus formed, is then removed from the boiler and pulverized. In order to convert this into cinnabar, three large earthen subliming pots are placed in a furnace, and gradually brought to a red heat by means of turf: at this time the cover of each (which consists of a simple square plate of iron) is removed, and the contents of an earthen vessel holding about a pint and a half of ethiops, are poured into each pot. In a few seconds a column of flame rises out of the pots, to the heighth of five or six feet, and, as soon as it begins to lessen, the further escape of the contents is prevented by putting on the iron cover. In a short time after, a second charge is poured in, to which succeeds a third, and so on, till at the end of thirty-four hours the whole of the ethiops has been equally divided between the three pots, making 410 lbs. for each. The fire is now kept up as steadily as possible for thirty-six hours longer, in order to accomplish the sublimation, care being taken to stir up the materials at the bottom of the vessels at least once every half hour, by an iron rod made for the purpose and introduced at the top. At the same time the workman ascertains how the process is going on by the flame which appears when the cover is removed; if it rises to the heighth of two or three feet, the heat is too great, as on the other hand it is too feeble if the flame only lightly quivers about the mouth of the pot; the proper temperature is marked by the flame rising vigorously, yet not exceeding three or four inches in heighth. When the last thirty-six hours are expired, the furnace is extinguished, and the whole allowed to cool: the subliming pots are then taken out, the iron hoops with which they are bound are knocked off, and the pots themselves are broken; the cinnabar is found sublimed in the upper part of the vessel to the amount of 400 lbs. being 10 lbs. less than the ethiops that was put in: or in other words, the loss of weight sustained by the conversion of ethiops into cinnabar, amounts to 2⅘ per cent.

Cinnabar when re-sublimed undergoes no alteration except that a variable though large proportion is lost, owing to the combustion of the sulphur and volatilization of the mercury. If cinnabar instead of being heated in close vessels, is put into an earthen test, and heated nearly to obscure red, a total decomposition takes place; the sulphur is converted into sulphureous acid, and the mercury flies off in the state of vapour. Long exposure to air and moisture seems to have no sort of action on cinnabar or ethiops; but they are both decomposed by dry distillation with barytes, lime, and the fixed alkalies, and with the following metals, iron, copper, tin, lead, silver, cobalt, nickel, bismuth and antimony. In all these cases the sulphur of the cinnabar combines with the added alkali or metal, while the mercury passes over in the liquid state.

A remarkable circumstance attending the decomposition of cinnabar by iron filings, is the production of an odour resembling that of sulphuret of ammonia according to Sage, and of ammonia according to Beaumé: this odour is so strong and permanent in the balloon receiver of the distillatory apparatus, that it remains very perceptible for several days, even though the vessel is exposed to the open air. The ammonia however thus developed, is in all probability neither formed by this process nor liberated from the cinnabar, but from the iron filings, for, according to the interesting experiments of Dr. Austin (see Ammonia, p. 67) it is readily generated by exposing moist iron filings to an azotic atmosphere.

In the moist way none of the acids have any action on cinnabar, except the concentrated sulphuric and the nitric: the former oxygenates the mercury and converts it to sulphat, sulphureous acid being disengaged; the latter oxygenates both the mercury and the sulphur, nitrous gas being given out, and sulphat of mercury being the result.

If a solution of either of the fixed alkalies in a perfectly caustic state, is boiled almost to dryness upon pulverized cinnabar, an extremely nauseous odour is disengaged, the alkali becomes more or less charged with sulphur, and globules of running mercury are produced.

The component ingredients of sublimed cinnabar are mercury and sulphur, in the constant proportion, according to Proust,[x] of 85 of the

[u] Ann. de Chem. iv. p. 25.

[x] Journ. de Phys. liii. p. 92.

former to about 14.5 of the latter. This result was obtained by decomposing cinnabar by means of reguline antimony, a method in some respects preferable to the more usual one by iron filings, especially on account of the ready fusibility of the sulphuret of antimony.

Some attempts have been made to prepare cinnabar by substituting the oxyds and even the salts of mercury to the simple metal, but for the most part with no improvement in the colour of the cinnabar, and at the imminent hazard of occasioning a violent explosion. Bayen was the first chemist who observed the fulminating property of the oxyds of mercury when heated with sulphur, and these mixtures have hence received the name of Bayen's fulminating mercury. The most powerful of these mixtures is thus prepared:[y] to a solution of nitrat of mercury add limewater, as long as any precipitate falls down, decant the clear liquor and wash the pulverulent oxyd with repeated portions of water, after which dry it on a water bath, and then grind it carefully in a mortar, with $\frac{1}{6}$ of its weight of flowers of sulphur. This powder when laid on a hot iron explodes with considerable force, no doubt in consequence of the sudden deoxydation of the mercury and the rapid combustion of part of the sulphur: for if it is performed in a close vessel to prevent the dissipation of the powder, the result of its decomposition will be a reddish violet coloured sulphuret, similar to that procured in the usual manner. Corrosive muriat of mercury rubbed up with the sulphur produces in like manner a violently explosive compound, while on the other hand calomel and sulphur afford by dry distillation cinnabar and corrosive muriat without any explosion; the reason of which is that the calomel divides itself into two portions, of which one is converted into cinnabar by combining with the sulphur and letting go its oxygen and muriatic acid, which being absorbed by the other portion of calomel, convert it into corrosive sublimate.

Sometimes cinnabar is prepared in the laboratory, though not in the large way, from corrosive sublimate and sulphuret of antimony, by distilling them together in the proportion of three of the former to one of the latter: in this case a double decomposition takes place; the oxygen and muriatic acid of the mercurial salt combine with the antimony, while the sulphur of this last unites with the mercury: hence during the process the products appear in the following order; first, the corrosive muriat, or butter, of antimony, passes into the receiver, then some undecomposed corrosive sublimate makes its appearance, and lastly, at a red heat, the cinnabar rises and attaches itself to the neck of the retort.

The action of mercury and its oxyds in the moist way upon the alkaline sulphurets, hydrosulphurets, and hydroguretted sulphurets, is very striking, and has received much attention from various chemists, though from the natural intricacy of the inquiry many difficulties yet remain to be cleared up.

It was an observation by Schultz,[z] in the German Ephemerides, that first of all we believe attracted the attention of chemists to this subject. He observes that if 36 grains of mercury be put into an ounce vial, with half an ounce of Boyle's fuming liquor, for a few days, and is frequently shaken during the interval and occasionally exposed to a gentle heat, the mercury will become at first black, and after a while will be wholly changed into cinnabar; when this has taken place, the supernatant liquor will be found to have lost its odour and colour, and will be covered with a saline pellicle. Hoffman and Wiegleb verified this observation and supported it by some new experiments, to which Beaumé soon after made some very valuable additions. He put into a vial some mercury with twice its weight of volatile liver of sulphur; upon agitating the mixture the mercury was immediately converted into a black powder, which three days after was found to have assumed the appearance of cinnabar, and crystallized in thick and very short prisms. 2. Sulphat of mercury being mixed with volatile liver of sulphur, a considerable heat and ebullition was produced, and the mercury became black; three days after, the supernatant liquor now colourless was poured off, and a fresh portion of liquid sulphuret was added, in the space of two days more the precipitate was changed into cinnabar. 3. To a solution of nitrated mercury volatile liver of sulphur was added as in the former cases, a considerable heat was produced and a copious black precipitate fell down, which in the space of a week had acquired a brick colour; the clear liquor was then poured off, and replaced by a fresh quantity of ammoniacal sulphuret, by which in the space of a few hours the colour of the precipitate was raised to a bright scarlet, fully equal to that of the best sublimed cinnabar. 4. A mercurial ethiops was made in the usual way by melting together four parts of mercury and one of sulphur, this was pul-

[y] Sage Elem. de Mineral. ii. p. 58.

[z] Coll. Acad. vi. p. 30.

verized and put in a vial with volatile liver of sulphur, by which in the space of half an hour it was converted into fine cinnabar. Similar effects to the above were observed to take place when a fixed alkaline liver of sulphur was made use of, only the change of colour from a black to red was considerably slower, and the colour itself was less pure and brilliant. The last improvement in the preparation of cinnabar in the moist way, was made by M. Kirchoff, of Petersburgh, and Count Mouffin Pouschin.[*] Three hundred grains of mercury and 68 grains of sulphur, are to be triturated in a porcelain cup with a glass pestle, a few drops of caustic potash being added to expedite and perfect the combination of the two ingredients: when a perfect ethiops is thus formed, there is to be added 160 grains of potash dissolved in an equal quantity of water, and the cup with its contents is to be heated over a lamp, care being taken to continue without interruption the trituration with the glass pestle. In proportion as the liquid evaporates fresh water must be added so that the ethiops may be constantly covered nearly to the depth of an inch. In the space of about two hours the colour begins to change from black to brown, and then no more water is to be added, but the trituration is to be continued as before. As soon as the mass acquires a gelatinous consistence the colour becomes more red and brighter with great rapidity: this is the most critical point of the whole process; for if the heat is not continued a sufficient length of time the utmost perfection of colour is not attained, and if it is persisted in only two seconds too long, the tint is degraded to a dirty brown, incapable of being amended.

Thus far the preparation in the moist way of this beautiful colouring substance was carried by M. Kirchoff, to which the following important additions were made by Count Mouffin Pouschin. First, the cup with its contents should be removed from the lamp or sand bath before the cinnabar has acquired its full degree of redness, and kept for three or four days at a temperature of 100° Fahr. stirring it up and adding a little water from time to time; at the expiration of this period the mass being allowed to become nearly dry, will be found to have acquired all the vividness which the successful accomplishment of Mr. Kirckhoff's process could have produced without the risk of destroying it by too long continuance of the heat. In order to separate the alkaline sulphuret from the cinnabar, it must be mixed with boiling water in the proportion of about a quart of the latter to an ounce of the former: after stirring the whole up for a few seconds the water will become quite black, and is to be poured off as soon as the cinnabar has subsided: the edulcoration is to be compleated with fresh parcels of hot water, till all the hepatic taste and odour is entirely washed away, and now the cinnabar will be very beautiful, differing from the common sublimed by a slight tint of yellow. A farther improvement in the cinnabar may now be brought about by the process of washing over: for this purpose let two or three ounces be put into a glass jar with some cold water, and mix the whole accurately by stirring, then, after an interval of a few seconds to allow the heavier particles to subside, pour the turbid water into a dish, and drain it off again as soon as it has become clear. The cinnabar thus separated will be found to be very brilliant, and approaching to carmine: the residue may be treated twice more successively in the same manner, and two more parcels of cinnabar inferior to the first, but still very good may be obtained, the residue is a brown sulphuret of mercury of no value as a pigment. To give the cinnabar the highest degree of beauty it is now to be dried slowly, and then is to be laid in small quantities at a time on a plate of glass or glazed earthenware, pretty strongly heated; the colour in an instant becomes brown, and then a very dark violet grey; it is now to be thrown upon a cold plate, where it passes in an instant to a brilliant carmine red.

Concerning the nature of the chemical action that takes place in the preparation of mercury by the moist way, there has been much controversy, nor is the subject even yet entirely free from difficulties. From the experiments however of Proust, Berthollet, and other chemists, it appears 1st, that the pure and recently prepared alkaline hydrosulphurets have no action on metallic mercury; but that when by exposure to the air these hydrosulphurets become coloured and converted into hydroguretted, or more properly into hydrosulphuretted sulphurets, the mercury decomposes them by uniting with the sulphur, and thus reducing them again to the state of simple hydrosulphurets; the mercury is by the same process changed into the black sulphuret, and is sparingly soluble in the supernatant hydrosulphuret. As soon however as the black sulphuret is changed to cinnabar it

[*] Nich. Journ. 4to. II. p. 1.

ceases to be soluble in an alkaline hydrosulphuret, whence the supernatant liquor at the conclusion of this process consists merely of the alkali combined with a variable proportion of sulphuretted hydrogen, as is manifest from its giving out sulphuretted hydrogen, but no sulphur, by the action of acids.

2. If instead of an alkaline hydrosulphuret, a liquid alkaline sulphuret, holding as little as possible of hydrosulphuret be employed, the action of the mercury is immediate, the whole of the sulphur combines with the metal, and the ethiops thus produced is partly taken up by the alkali, but is deposited again as soon as the ethiops is converted into cinnabar, so that the clear and colourless supernatant fluid contains now only alkali with the casual quantity of sulphuretted hydrogen originally contained in it, and which appears to have been entirely inert during the whole process.

3. If to a pure alkaline hydrosulphuret there be added some red oxyd of mercury, the liquor becomes hot, acquires a yellow colour, and if the proper quantity of metallic oxyd has been used, both the hydrosulphuret and metallic oxyd will be entirely decomposed; the oxygen of the one and the hydrogen of the other by their combination will produce water, the mercury will saturate itself with sulphur and become ethiops, and the supernatant liquor is a pure alkaline sulphuret from which the acids are capable of precipitating the sulphur, but of not separating a single atom of sulphuretted hydrogen.

4. If a solution of common alkaline hepar or hydrosulphuretted sulphuret, be first brought to the state of simple sulphuret by the addition of a little red oxyd of mercury, and there be afterwards added a fresh portion of oxyd, a great increase of temperature is observed, part of the sulphur is converted into sulphureous acid by a portion of the oxygen, while the remainder of the oxygen quits the metal and assumes the gaseous state, causing an effervescence during its disengagement: when this has taken place the supernatant liquor contains the alkali of the hepar with a little sulphureous acid, and often a small quantity of red oxyd if an excess of this substance has been made use of.

The deduction from these experiments is, that neither oxygen nor sulphuretted hydrogen enter into the composition of ethiops or cinnabar; and it is highly probable that the only difference between them consists in the proportion of sulphur.

Phosphorus may be made to combine with mercury[b] by distilling together equal parts of red oxyd of mercury and phosphorus, together with a little water: during the process the red oxyd becomes black and unites to the phosphorus, and phosphoric acid is produced. This combination may be more easily effected according to Dr. Thomson, by using the grey oxyd of mercury. Phosphorus and mercury in the metallic state cannot be made to combine, except the latter is in a state of extreme division. Phosphuret of mercury is a substance of a moderately solid consistence, a black colour, and may be cut with a knife; when exposed to dry air it exhales white vapours of phosphorus. It is decomposed by distillation, the phosphorus first comes over and then the mercury, each substance being found in the receiver perfectly separate.

Mercury is capable of uniting with many of the other metals, and these combinations have obtained the name of Amalgams. They have received considerable attention from various chemists, though by no means so much as their chemical importance deserves. Before we proceed to notice the particular amalgams we shall mention a few general observations that are applicable to all of them.

First with regard to the preparation of amalgams. It may be remarked that the care necessary in their preparation depends considerably on the degree of affinity subsisting between the mercury and the other metal. Where the affinity is very powerful, as is the case with gold and silver, the fluidity of the mercury without any other condition will effect a combination even at the common temperature. Other metals of stronger cohesion or weaker affinity require the assistance of heat to make them amalgamate; while those metals that are infusible, except at a temperature equal to the rapid volatilization of mercury, as copper, require peculiar precautions to bring about a combination. Amalgams may be made either solid or fluid, according to the proportion of mercury that enters into this composition; the quantity however of this last that is required to give the amalgam a fluid state, is different for each metal.

2. All the appearances that happen during the composition of metals with mercury indicate a real solution of one in the other, owing to the chemical attraction between the bodies so uniting. Hence during amalgamation as is the case in all other instances of solution, a very observable change of temperature takes place. Another remarkable phenomenon is the tendency to oxydation which both metals exhibit during their combination. Thus if bismuth,

[b] Mem. de Pellet. ii. p. 42.

tin, or lead, are amalgamated with mercury, a quantity of black powder is formed as the process advances, which is a compound oxyd of mercury and the other metal.

The specific gravity of amalgams as of all other alloys, is different from the mean specific gravity of their component parts.

The more decidedly crystalline form of amalgams is a circumstance that remarkably distinguishes them from other alloys. All amalgams are brittle, and any of them when broken exhibits a granular or laminated texture which by the microscope will be found to be owing to a multitude of minute crystals applied by their surfaces to each other, but not adhering with any considerable force. Induced by these appearances M. Sage succeeded in obtaining regular crystals of most of the amalgams by the following method. Having prepared a very fluid amalgam by adding from four to six times as much mercury as of the other ingredient, he put it into a retort, and by a gentle sand-bath heat distilled over a fourth or even a third of the mercury, the residue being then allowed to cool gradually, was found regularly crystallized at the bottom of the vessel.

Amalgams may be decomposed by heat; but the last portions of mercury are not driven off without a much higher degree of heat than is required for the volatilization of pure mercury. Hence a large proportion of the volatile metals and a smaller even of those which are considered as very fixed, unites with the mercury and is carried over by it.

As each metal has its peculiar affinity for mercury, it is obvious that an amalgam may be decomposed by the addition of a metal that has a stronger attraction for mercury than that of which the amalgam is composed: upon this subject however no very accurate experiments have been as yet made, which is the more to be regretted as it would assist the investigation of the interesting and important, but difficult subject of metallic alloys.

Gold and Mercury.

The strong affinity of these two substances may be seen by dropping a globule of mercury on a plate of gold: the sphericity of the globule will almost immediately be lost, and the mercury wherever it spreads covers the surface of the gold with a bright silvery stain. The amalgam of gold may be prepared by grinding together gold leaf and mercury in a mortar with a little hot water, or by digesting together mercury and gold filings or clippings in a crucible or flask, till the combination is compleat. Even if a bar of gold of considerable thickness be immersed in mercury for a few days at the common temperature, it will not only be superficially corroded, but will be rendered so brittle as to break with a very moderate force; and its fracture will exhibit minute threads of mercury that have insinuated themselves through its pores and thus destroyed its ductility. Amalgam of gold is of a yellowish white colour and crystallizes in tetrahedral prisms, when composed of six parts of mercury to one of gold. It melts at a moderate temperature and at a higher the mercury flies off leaving the gold behind. If a very fluid amalgam consisting of 1 part of gold to 48 of mercury, be exposed with access of air to a moderate heat (as in the preparation of precipitate *per se*) not only the mercury, but even the gold will be oxydated. At a somewhat higher heat both oxyds are again reduced to the metallic state.

Silver and Mercury.

Silver in the order of its affinity for mercury stands next to gold, and its amalgam may be prepared in precisely the same way. Its colour is silvery white, it crystallizes in octohedrons; its specific gravity is remarkable, being greater even than that of mercury, the heaviest of its ingredients, hence it sinks in this fluid when at the common temperature, as was first observed by Gellert. That most beautiful preparation the *Arbor Dianæ*, is a crystallized amalgam of silver, for a particular account of which we refer the reader to the article Silver.

Tin and Mercury.—Lead and Mercury.—Zinc and Mercury.—Bismuth and Mercury.

These amalgams are prepared by melting the solid metal in a crucible and adding to it as soon as the fusion is compleated an equal weight of mercury previously made nearly boiling hot in another crucible, and then keeping the mixture at a temperature fully equal to preserve its fluidity till the combination is compleat. All these amalgams are possessed of considerable solidity; their colour is intermediate between that of the metals of which they are composed; and their texture is granular. If equal parts of the solid amalgams of lead and bismuth are triturated in a mortar, a combination speedily takes place, and the result is a compound amalgam very nearly as fluid in the common temperature as pure mercury: advantage is taken of this property by fraudulent dealers to adulterate mercury by a mixture of these two cheaper metals, and when the mercury amounts to 70 or 80 per cent. it is not easy from the mere look to detect the cheat. If the mixture of these two amalgams be made in the palm of

the hand a fenfation of cold is experienced during the combination nearly equal in intenfity to that produced by the evaporation of common fpirit of wine. If a ftick of tin be placed in this fluid compound amalgam when the weather is cool, it will be found in the courfe of two or three days to be confiderably corroded by the mercury, at the fame time cubic cryftals of amalgam of bifmuth, apparently with a very fmall proportion of mercury, will be found adhering to the tin. A fimilar effect will be produced if equal parts of the amalgams of tin, lead, and bifmuth are mixed together at the temperature of boiling water, and the compound be then expofed for a few days to a very flight froft; cubic cryftals of bifmuth nearly a quarter of an inch long will be found floating on the furface.

Antimony and Mercury.

The affinity between thefe two metals is but feeble, and the heat neceffary for the fufion of antimony being equal to that at which mercury is volatilized they cannot be conveniently mixed by fufion. They may be made to combine however by taking fome perfectly pure regulus of antimony, reducing it to a fine powder, and then triturating it for a confiderable time with mercury and boiling water. The properties of this amalgam have not been examined.

Copper and Mercury.

Thefe two metals for the fame reafon as that alledged in the former paragraph, cannot be combined by fufion. Filings of copper and mercury may by long trituration in hot water be made to unite. But the moft effectual method of preparing this amalgam is the following. To a hot folution of fulphat of copper add a little muriatic acid and a few fticks of zinc, and boil the mixture for about a minute; by this means the copper will be precipitated in its metallic ftate, and in a finely divided fpungy form: take out the pieces of zinc, pour off the liquor and edulcorate the copper thoroughly with hot water, then pour on it a fmall quantity of dilute nitrat of mercury, by which every particle of copper will be covered in an inftant with a coating of mercury; now add running mercury to the amount of two or three times the weight of the copper, and a very flight trituration will combine them fo far that the completion of the procefs may be effected by heating the mixture for a few minutes in a crucible. The amalgam of copper is of a reddifh white colour, and has not as yet been examined.

Iron and Mercury.

Iron is generally confidered as incapable of uniting with mercury. It is ftated however in Crell's Journal[c] that Mr. Vogel has fucceeded by the following procefs. Take half an ounce of iron filings and one ounce of alum and rub them together to a very fine powder, add to this from an ounce to an ounce and a half of mercury, and triturate till the amalgam begins to be formed: a little water is now to be poured in, and continued agitation had recourfe to for an hour: the alum is now to be diffolved out and the amalgam of iron will remain behind.

A compound amalgam of iron and zinc may be prepared in the following way.[d] Make an amalgam in the ufual method of equal parts of zinc and mercury: mix this with half its weight of clean iron filings, and rub the whole accurately together in a mortar; this being finifhed, pour on fome muriat of iron and continue the trituration as long as any effervefcence or difengagement of hydrogen gas takes place, when this ceafes pour off the fluid and add more muriat, repeating the procefs till the laft addition of muriat ceafes to caufe any effervefcence. The amalgam will now be confiderably ftiff, and upon breaking it the particles of iron will appear imperfectly combined with the mercury. Being now carefully dried, it muft be preffed into an earthen crucible and covered with tallow to prevent its oxydation, and a heat being applied enough to volatilize the tallow, the amalgam will remain behind and is compleated. This compound amalgam has a filvery white colour, an uniformly granular texture, in hardnefs is nearly equal to reguline antimony, and is not fubject to ruft by expofure to the air. It is not capable of affecting the magnetic needle.

A [e]compound amalgam of iron and tin is readily and effectually prepared by melting together a few iron nails with about four times their weight of grain tin, and then digefting this alloy for a few hours in boiling mercury till it is diffolved. This amalgam is of a filvery white colour, has a confiderable toughnefs approaching to malleability, and attracts the magnetic needle.

Brass and Mercury.

This amalgam may be expeditioufly and compleatly prepared by triturating an amalgam of zinc with fulphat or muriat of copper till the liquor becomes colourlefs, and then keeping the mafs in fufion for a few minutes to compleat the combination.[f]

[c] Ann. de Chem. p. 39. [d] Orig. Exper. [e] Ditto. [f] Ditto.

The ufes of mercury and its preparations are numerous and important. Its chief confumption is in the feparation of gold and filver from their ores: it is alfo largely employed by the gilders. It is of ineftimable advantage to experimental philofophy as affording a fluid the moft ufeful of all others for thermometers and barometers, and is of great fervice to modern chemiftry for confining thofe gaffes that are abforbed by water. The arts are indebted to mercury for the filvering as it is called of mirrors, the gilding of buttons and other articles, and for that beautiful pigment cinnabar. The falts of mercury are of important ufe in the laboratory; and medicine is indebted to this metal in almoft all its combinations for fome of its moft powerful and beneficial inftruments.

MERCURY FULMINATING (*Howard's*). This fingular preparation was difcovered by E. Howard, Efq. F.R.S. in a feries of experiments on the action of alcohol on nitric acid. [a]

The mode of preparing it is the following. Diffolve 100 grains of mercury in an ounce and a half (by meafure) of common nitric acid of the fhops, which is of the fpecific gravity of about 1.3, affifting the folution by heat. When cold pour the folution upon 2 ounces (by meafure) of ftrong alcohol, and apply a moderate heat till the mixture begins to effervefce. A white fume then begins to undulate on the furface of the liquor, during which a white powder precipitates which is the fulminating mercury. This powder is to be immediately wafhed with cold water, and dried at a heat not much exceeding that of boiling water.

In making this powder the precife ftrength of the alcohol and of the acid are not of great importance. The quantity produced varies extremely, but is on an average about 125 grs. from 100 of mercury. The colour is in general white. The temperature required for mixing the nitrous folution and the alcohol, fhould be about 80° or 90°.

This powder is remarkable for the extreme force of detonation which it poffeffes when exploded by various methods. Thefe are either concuffion, for when a grain or two (and no more fhould be ufed for experiment) is laid on an anvil and ftruck fmartly with a hammer, it detonates with a ftunning report, leaving the iron much indented; or heat, the proper degree of which the difcoverer finds to be about 368° of the thermometer; or the electric fpark; or the flint and fteel in the method of common gunpowder; or the contact of ftrong fulphuric acid. It is equally inflammable in vacuo, as in air. Fulminating mercury differs from gunpowder peculiarly in this circumftance, that the force of explofion of the mercurial powder is almoft immenfe and far exceeding that of gunpowder fo as to fplit into pieces and utterly to rend any fubftance by which it is confined; but on the other hand the projectile force is very feeble and far fhort of that of gunpowder. So that when the fulminating mercury was attempted to be ufed in fire arms, a very fmall portion of it burft ftrong pieces of ordnance, but where the piece ftood the explofion, the ball was expelled with only a trifling force.

The compofition of this powder is fomewhat complex, and the analyfis rather obfcure. Mr. Howard examined it chiefly in the following manner. Sulphuric acid, diluted with as much water, when digefted on the powder with gentle heat, difengaged a quantity of gas amounting to from 28 to 31 cubic inches from 50 grains of the powder. Of this gas the greater part was carbonic acid, but after this had been abforbed by ammonia there remained about 5 to 7 inches of a gas refembling in every refpect the *nitrous etherized gas* after fimilar expofure to dilute fulpuric acid. This peculiar gas is highly inflammable, and enlarges the flame of a taper like the gaffeous nitrous oxyd, and refembles the latter in other properties, but differs from it in being permanent over water and in refufing to detonate with hydrogen. The refidue of 100 grains of the fulminating mercury after treatment with fulphuric acid was an infoluble powder weighing 84 grains, and was found to confift of *oxalat of mercury* with a few globules of mercury in the metallic ftate. It was proved to be oxalat of mercury by digefting it with nitrat of lime, whereby (by a double decompofition) nitrat of mercury and oxalat of lime was produced. The fulphuric liquor after feparation of the infoluble powder was then faturated with carbonat of potafh, and 3.4 grains of carbonat of mercury were collected.

From the refult of many experiments, Mr. H. concludes that 100 grains of the fulminating powder confift, nearly, of 21.28 of oxalic acid, 64.72 of mercury, and the remaining 14 parts neceffary to compleat the 100, are to be allowed for the nitrous etherized gas and an excefs of oxygen with which the mercury appears to be united. But it muft be obferved that the exact compofition of this fingular powder ftill requires much elucidation. The carbonic acid which forms fo large a portion of the gas expelled by

[a] Phil. Tranf. for 1800.

fulphuric acid is probably to be attributed to the decompofing action of this acid on part of the oxalic acid, whence arifes another fource of difficulty in obtaining an exact analyfis.

As the original materials of which the fulminating mercury are compofed are nitric acid, alcohol, and mercury, the oxalic acid muft be formed during the procefs by the action of the acid on the alcohol, (a fact which has been frequently obferved in experiments on nitrous *ether*) and fo completely is the acid decompofed that no trace of it appears (as acid) in the powder when compleat.

The quantity of mercury actually obtained from 100 grains of the powder by no means equals the quantity employed in the procefs, for 100 grains of mercury produce at leaft 120 of fulminating powder, whence if the whole of the mercury went to the compofition of the powder, 100 grains of this latter ought to contain 78 grains of mercury, but only about 64 are actually obtained. This deficit of 14 grains from 78, Mr. H. fuppofes to be volatilized in the denfe white fume which arifes during the mutual action of the alcohol and nitric acid, and which when condenfed in bottles filled with a folution of muriated ammonia was found to give a mercurial precipitate with ammonia, precifely fimilar to that produced by ammonia and corrofive muriat of mercury.

Mr. Burkitt has the following ufeful practical remarks on the preparation of this powder.[b] Three ounces of mercury were diffolved in $1\frac{1}{4}$ lb. of nitrous acid. The folution was poured into a large retort, into which had been previoufly put $1\frac{1}{4}$ lb. of alcohol warmed to 80°. In three minutes the ufual effervefcence took place and the gas was conveyed into a large globe receiver in contact with water. In about twenty minutes the procefs was compleat, without the affiftance of artificial heat, and the fulminating powder precipitated, which when wafhed and dried weighed 3 ounces and 1 dram. The water in contact with the gas was covered with 4 ounces of nitric ether which floated on it.

It is a very remarkable and quite unaccountable circumftance obferved by Mr. Cruikfhank, that the mercurial powder when exploding will not fire gunpowder; for on fpreading fome of the former on paper, and fhaking fome gunpowder over it, and firing the mercurial powder, the grains of gunpowder were collected entire after the explofion.

MERCURY *Fulminating (of Bayen.)* See Mercury.

MERGEL. See Marl.

MEPHITIS is a general term for *foul* or *unrefpirable* air of whatever kind it be, and ufually is applied either to azotic or carbonic acid gaffes.

MESOTYPE. See Zeolite.

METAL. It is worthy of remark that the definitions of chemical bodies, in proportion as that fcience has advanced, have been drawn lefs from their fenfible qualities and more from their chemical ones, from which if fome advantages have been derived yet confiderable difadvantages have alfo hence arifen. Thus if a metal be defined, *a combuftible or oxydable fubftance capable when in the ftate of oxyd of uniting with acids and forming with them compound falts*, we fhall be in poffeffion of a character applicable to all metals and to no other clafs of bodies, and yet fhall not have mentioned one of thofe properties which doubtlefs firft led to the difcovery of metals, and in which their principal value as fuch muft always confift.

The only metals known to the ancients were gold, filver, copper, iron, tin, lead and mercury; and all thefe with the exception of the laft, being malleable, ductile, fufible and capable of being polifhed, their ufe moreover chiefly depending on thefe properties, the qualities of malleability, ductility, fufibility and of receiving a polifh were confidered as effential to and characteriftic of metallic fubftances. At length the lift of ancient metals was augmented by the addition of three new ones, antimony, bifmuth and zinc, but thefe, though agreeing in other refpects with the former, being more or lefs brittle, it was found expedient to fubdivide this clafs of natural fubftances into the malleable or proper metals, and the brittle or femi-metals. Much about the fame time arofe the chemical diftinction of metals unalterable by expofure to the air at a fufing heat, and thofe which in the fame circumftances were liable to be calcined. The former of thefe were called perfect or noble metals, and the latter imperfect or bafe metals: of the bafe metals fome were afterwards found to be acidifiable, whence arofe another ground of diftinction.

The number of metals at prefent known, amounts to 27, which may be tabularly arranged as follows.

[b] Phil. Mag. vol. 17.

METALS
- *oxydable by heat*
  - *acidifiable*
    - *volatile* - - Arſenic
    - *fixed* - - - Molybdena, Tungſten, Chrome, Columbium
  - *not acidifiable* -
    - *brittle* - - -
      - *infuſible or granular* - Oſmium, Uranium
      - *fuſible* - - - Tantalium, Titanium, Tellurium, Manganeſe, Cobalt, Antimony, Biſmuth
    - *malleable* - - - - - - - - Zinc, Lead, Tin, Iron, Copper, Mercury
- *not oxydable by heat* - - - - - - - - - - - - - - - - - -
  - *granular and brittle* - Iridium, Rhodium
  - *fuſible and malleable* - Palladium, Nickel, Platina, Silver, Gold

We ſhall now proceed to notice briefly the generic characters of metallic ſubſtances.

One of the moſt remarkable is the peculiar luſtre which their ſmooth or poliſhed ſurfaces exhibit, and which from its being eminently characteriſtic of theſe ſubſtances has been called the metallic luſtre: ſome other minerals indeed, as mica, Labrador felſpar, &c. poſſeſs this luſtre in a ſtriking degree, but in all theſe it is always attended by a greater or leſs variableneſs of colour which never takes place in the pure metals, although it is very ſtriking in many of their ores.

The next remarkable property of metals is their opacity, which though very conſiderable is by no means abſolute, as ſome chemiſts have inadvertently affirmed. A piece of common leaf gold if held between the eye and a luminous object, will be found to tranſmit a green light; ſilver in the ſame circumſtances affords a white light, and it is extremely probable that all the other metals if attenuated in the ſame degree would alſo be tranſparent.

In ſpecific gravity the metals exceed all other known ſubſtances; the native ſulphat of barytes, the heavieſt of earthy minerals, being leſs than 4½ times as heavy as water, whereas the ſpecific gravity of tellurium, the lighteſt of the metals is more than ſix times as great as that of water. Of ſome of the more recently diſcovered metals the ſpecific gravity has not yet been aſcertained, nor are chemiſts by any means agreed reſpecting the relative gravity of the reſt. This ariſes partly from a difference in the purity of the ſpecimens which have been the ſubjects of experiment, but principally from the variations of denſity which the ſame metal will exhibit according to the preſſure that it has been expoſed to, either during the act of ſolidifying from fuſion, or at any ſubſequent period. The following is a liſt of the metals hitherto examined in the order of their ſpecific gravities.

Platina (hammered) - - -	23.00
Gold - - - - - - - - -	19.25
Ditto laminated - - - -	19.36
Tungſten - - - - - - -	17.60
Mercury (fluid) - - - -	13.56
Palladium - - - - - -	11.87
Lead - - - - - - - - -	11.35
Rhodium - - - - - - -	11.00
Silver - - - - - - - -	10.47
Ditto laminated - - - -	10.51
Biſmuth - - - - - - -	9.82
Uranium - - - - - - -	9.00
Molybdena - - - - - -	8.60
Nickel - - - - - - - -	8.51

Arfenic - - - - - - -	8.31
Ditto, according to Fourcroy	5.76
Copper - - - - - - -	7.78
Ditto in wire - - - -	8.89
Cobalt - - - - - - -	7.64
Iron - - - - - - - -	7.60
Ditto hammered - - -	7.78
Tin - - - - - - - -	7.29
Zinc - - - - - - - -	7.06
Manganefe - - - - - -	6.85
Antimony - - - - - -	6.71
Tellurium - - - - - -	6.11

The fufibility of metals is a property that eminently contributes to their ufefulnefs, fince without this it would fcarcely be poffible to feparate them from the earths and other impurities with which they are naturally mixed, unlefs at an immoderate expence both of time and labour; not to mention the vaft advantage as well as in accuracy as economy, of producing a veffel or inftrument by pouring the fluid material into a mould inftead of laborioufly carving it out from the block by the hammer and chizel or turning it in a lathe. The range of temperature at which the various metals become fluid, extends from the higheft heat that our furnaces can produce, to a degree of cold never occurring naturally, except in Siberia and the other inclement regions of the fartheft north. The following is the order of fufibility as far as it has hitherto been afcertained.

Mercury -	at — 39° Fahrenheit.
Tin - - Bifmuth - Lead - - Tellurium - Zinc - -	from 442° Fahr. to a temperature juft below that of red heat.
Antimony -	low red heat.
Silver - - Copper - - Gold - -	from a bright or cherry red to a low white heat.
Cobalt - - Nickel - - Iron - - - Palladium - Manganefe - Titanium -	from a full white heat to the greateft heat of a wind or blaft furnace.
Platina - -	capable of being rendered foft and cohefive, but fcarcely fufible in the greateft furnace heat.

Some metals however appear to be abfolutely incapable of proper fufion, on which account they can only be obtained in the ftate of flightly cohering fcales or grains, very different from the button formed by the fufible metals. That this granular form is not occafioned by a deficiency of heat, is manifeft from the volatilization of thefe metals without fufion by an increafed temperature. Thus arfenic is converted into vapour at the heat of melting lead, tungften at a very intenfe white heat, and perhaps molybdena, chrome and uranium at a fomewhat higher temperature. Many of the properly fufible metals are alfo known to be volatilizable at a heat confiderably above their point of fufion, and this is probably the cafe with all of them. Thefe two effects however, though depending on the progreffive energy of the fame caufe, heat, by no means follow the fame order; arfenic ranks the firft in volatility, then comes mercury, to which fucceed zinc and antimony. All the fufible metals may be obtained in a cryftalline form, by means which has been already related in the article CRYSTALLIZATION.

Another ftriking and valuable property of metals is their extenfibility. This by the ancients was reckoned one of the effential characters of metallic bodies, but has ceafed to continue fo in confequence of the difcovery of a number of metals deftitute of this quality. Its high importance however may be well judged of by obferving that for almoft all mechanical purpofes the intrinfic value of metals is intimately dependent on their extenfibility. Metals are extended either by hammering or laminating, in which cafe they are faid to be malleable, or by wire-drawing, when they are faid to be ductile. The metal of greateft malleability is gold, which may be beaten into leaves fo thin that they will float in the air like a feather: filver may alfo be reduced to nearly the fame ftate of tenuity: after thefe may be ranked in the following order copper, tin, lead, iron and zinc; this laft however in order to be perfectly malleable, muft be made fomewhat hotter than boiling water. The other malleable metals are platina, palladium, nickel and mercury, but no experiments have been made with fufficient accuracy to afcertain their proper place in the feries: it appears probable however that the three firft fhould be inferted between lead and iron. With regard to mercury, its extreme fufibility muft ever oppofe an infurmountable obftacle to the determination of its malleability. It might at firft fight appear to be a neceffary confequence that the ductility of metals fhould follow the fame order as their malleability, both properties being merely a mode of extenfion; but a little reflection on the procefs of wire-

drawing will evince that the ductility of a ſubſtance is compounded of its malleability and tenacity; hence iron, though by no means ſo malleable as tin or lead, greatly ſurpaſſes them in ductility. All metals, in a greater or leſs degree, while undergoing the proceſs of hammering or wire-drawing, give out heat and ſuffer a proportionable increaſe of ſpecific gravity; but at the ſame time and in the ſame proportion they become rigid and more diſpoſed to break or tear than extend evenly: their original ductility and ſoftneſs may however be reſtored by annealing, which conſiſts in heating them moderately and allowing them to cool gradually; by this the heat which was expreſſed from them is reſtored, and their ſpecific gravity is reduced to its original amount. The quantity of expreſſible caloric contained in tough bar iron is ſo great that by rapid hammering it may actually be made red hot, whereas lead by the ſame treatment has its temperature raiſed only a few degrees.

The tenacity of a metal is eſtimated by the weight required to break a wire of a given diameter when ſuſpended at one end of it while the other end is made faſt to a bar. The moſt accurate experiments on this ſubject are thoſe of Sickingen, from which it appears that

a wire of iron $\frac{1}{10}$ of an inch in diameter will bear	705. lbs. avoirdupois before it breaks,
——— copper ———	387.
——— platina ———	351.
——— ſilver ———	239.
——— gold ———	191.

The tenacity of tin is greatly inferior to that of gold, and the tenacity of lead is the leaſt of all.

On the chemical properties of metals a few words will ſuffice, as each individual metal is treated of much at length in its proper place.

Metals are ſimple ſubſtances; at leaſt if they are not abſolutely ſo, yet there is no inſtance of any one of them having been hitherto decompoſed, notwithſtanding the almoſt innumerable proceſſes to which they have been ſubjected for this very purpoſe. The metals are very generally by modern chemiſts ranked among the ſimple combuſtibles, and indeed in many reſpects a very ſtrong analogy exiſts between them. By mere heat they undergo no change except of form, becoming liquid or aſſuming a ſtate of elaſtic fluidity according to the degree of temperature: but when expoſed at the ſame time to heat and oxygen gas, they enter into active combuſtion and unite with oxygen, light and heat being evolved during the proceſs. Nor are they only capable of combining with oxygen when preſented to them in the ſtate of gas, but alſo of decompoſing many ſubſtances into which this ingredient enters by means of their ſtrong affinity for it. Hence atmoſpheric air, water, the compound acids, and ſeveral of the neutral ſalts are thus capable of being decompoſed; the metal becoming oxydized, and the other baſe with which the oxygen was at firſt united being either entirely deprived of it or reduced to a low ſtate of oxygenation according to circumſtances. The affinity for oxygen manifeſted by the different metals is extremely various in degree, ſome entering into active combuſtion when expoſed to atmoſpheric air at a heat ſomewhat greater than that required for their fuſion, as zinc and iron, while others in the ſame circumſtances are ſlowly oxydized without much appearance of combuſtion, and others again, as gold, ſilver and platina, appear wholly incapable of being oxydized by this proceſs. A ſimilar difference may be remarked in the habitudes of metals with regard to every mode of oxydation, whether through the medium of the decompoſition of water, of acids, or of the neutral ſalts. Some metals are capable of combining with oxygen in two or more proportions, as iron, lead and tin, but even in the higheſt ſtate of oxygenation they never aſſume acid characters; while on the other hand ſome metals, as arſenic, molybdena and chrome, when ſaturated with oxygen, are compleat acids, exhibiting every character of ſuch. Metallic oxyds and acids may all be brought back again to the reguline or proper metallic form by being expoſed to the action of any ſubſtance that has a ſtronger affinity with oxygen than they themſelves poſſeſs; thus charcoal, hydrogen, phoſphorus and ſulphur, though in certain circumſtances they are deoxygenized by the metals, are very capable in other circumſtances of decompoſing metallic oxyds by abſtraction of their oxygen.

Metals when in the ſtate of oxyd are capable of uniting with acids forming the metallic ſalts, with ſulphuretted hydrogen, and in ſome caſes with the alkalies; at a high heat they become more or leſs tranſparent, aſſume the vitreous texture, and are called metallic glaſſes; they are now capable of mixing with other vitreſcent mixtures, to which they communicate their own peculiar colours.

Metals in the reguline ſtate combine with each other, forming various ALLOYS, and with phoſphorus, carbon and ſulphur, forming the metallic phoſphurets, carburets, and ſulphurets.

MICA. Glimmer *Wern.* Mica, *Hauy and Broch.*

Its colour is aſh or ſmoak-grey, yellowiſh, greeniſh and blackiſh grey; it alſo occurs ſilvery white, bronze yellow, copper-red, browniſh red, tombac-brown, blackiſh brown, greeniſh black, and mountain green. It occurs moſt uſually diſſeminated, often ſuperficial, rarely in maſs, and ſtill more rarely cryſtallized. Its primitive figure is a ſhort ſtrait priſm with rhomboidal baſes, the alternate angles of which meaſure 60° and 120°. It alſo occurs in ſhort regular hexahedral priſms or tables. Sometimes the lateral edges are replaced by planes, forming an angle of about 100° with the baſe to which they adjoin, thus repreſenting a very ſhort hexahedral priſm terminated by very deeply truncated hexahedral pyramids. It alſo ſometimes preſents rectangular tables. The baſes of the cryſtals are ſmooth and ſhining: internally it is ſhining and very ſhining, with a reſinous, pearly, or metallic luſtre. Its fracture is generally ſtrait, curved, or undulatingly foliated, ſometimes, though rarely, divergingly radiated; its fragments are tabular and indeterminately angular. When in maſs it is compoſed of granular and wedge-ſhaped diſtinct concretions. When in thin plates it is tranſparent or ſemitranſparent; thoſe varieties with a metallic luſtre are only tranſlucent on the edges. It may be ſcraped eaſily by a knife, is flexible and moderately elaſtic, when in thin plates may be cut like ſoft horn, and is ſmooth but not unctuous to the touch. Sp. gr. 2.79 to 2.93.

Before the blowpipe mica fuſes with difficulty into an enamel, which, when black mica is employed, is uſually magnetic.

Mica has been analyſed by Vauquelin, and the variety called Muſcovy Talc by Bergman, with the following reſults:

	Vauq.		Berg.
Silex	50	—	40
Alumine	35	—	46
Lime	1.33	—	0
Magneſia	1.35	—	5
Oxyd of Iron . .	7.	—	9
	94.68		100
Loſs . .	5.32		

Mica is conſidered as belonging eſſentially to the primitive rocks, and for the moſt part aſſociated with quartz and felſpar, as in granite, gneiſs, and micaceous ſchiſtus: it is for the moſt part diſperſed through the entire ſubſtance of theſe rocks and occaſionally forms ſmall veins, in which laſt the maſſive and cryſtallized varieties are almoſt excluſively found. In the moſt ancient large grained granite plates of mica frequently occur of the length of three inches or more; and the veins of mica which occaſionally traverſe this ſpecies of rock have been known to afford plates nearly 5 feet ſquare. Mica in ſmall ſpangles is by no means unfrequent in the ſlaty ſandſtone that accompanies the independent coal-formation and the beds of alum ſlate: it is alſo met with, though more rarely, in the rocks of trap-formation.

The large plates of mica called Muſcovy Talc or Muſcovy Glaſs, are procured chiefly from Ruſſia; of late years a ſomewhat inferior kind has been dug in the province of Penſilvania in America: it is tranſparent, has a ſmoaky tinge, and is in common uſe inſtead of window-glaſs in the neighbourhood where it is procured. It was employed inſtead of glaſs in the windows of the Ruſſian ſhips of war, as not being liable to be broken by the concuſſion of the air during the diſcharge of heavy artillery, but it has the inconvenience of never being ſo tranſparent as glaſs, and of becoming dim by continued expoſure to the ſea air. Muſcovy Talc may be divided into plates of almoſt incredible tenuity, ſome of them according to Hauy being no thicker than $\frac{1}{500000}$ of an inch; this circumſtance added to its toughneſs and flexibility, render it peculiarly proper for incloſing objects to be inſpected by the ſolar microſcope. The gold and ſilver-coloured mica called vulgarly Cat's gold and ſilver, is employed with good effect in froſt-work ornaments inſtead of more coſtly materials.

MICACEOUS SCHISTUS. Glimmerſchiefer *Wern.* Schiſte micacé *Broch.*

Micaceous ſchiſtus is a ſpecies of rock belonging to the claſs of primitive ones, and is of great importance both in a geological and mineralogical point of view. Both its name and external characters are derived from the mica which it contains, and which is always the moſt ſtriking, and occaſionally the predominating ingredient. It conſiſts eſſentially of minute plates or ſpangles of mica lying all in one direction, with granular quartz interpoſed. The colour of the quartz is white or grey, that of the mica is ſilvery white, or greyiſh white with a metallic luſtre, ſometimes brown, and rarely greeniſh. The fracture of this mineral in the direction of the mica is ſlaty, though not pro-

perly laminated. When pure, it is hardly fusible without a flux.

In some varieties of micaceous schistus a considerable quantity of felspar is contained, when this is the case its texture becomes coarser, and it is scarcely to be distinguished from gneiss; other varieties consist entirely of mica and granular quartz, but this latter in so great a proportion to the other ingredient that its slaty texture is almost entirely obscured.

Micaceous schistus frequently incloses other minerals, particularly garnet, felspar, cyanite, and tourmalin.

Mountains of micaceous schistus are by no means so simple in their structure as those of granite and gneiss, since they frequently contain beds of primitive limestone, hornblende, slate, and rarely primitive gypsum; beds of actynolite, pyrites, galena, and other metallic ores are also occasionally met with. Some of the richest metallic veins are also situated in this species of rock, as is the case with most of the mines of Sweden and Norway, and with a considerable number of those in Saxony and Hungary. Micaceous schistus generally reposes on gneiss, and forms mountainous chains of considerable extent, though seldom of any great heighth. The most interesting chains of this species of mountain in Britain are the vales of the Tay, and the Tummel, Strath Errick, and Glen Roy, in the Scottish highlands.

Micaceous schistus, when pure, is in much request for the walls and hearths of furnaces on account of its great infusibility; it is also split into leaves for covering houses, though for this purpose it is inferior to slate.

MICARELLE. See PINIT.

MICROCOSMIC SALT is the compound PHOSPHAT *of Soda and Ammonia* (which see).

MILK. Milch. *Germ.* Lait. *Fr.*

This fluid, the next in importance of all the animal liquors to blood, has been examined very largely by different chemists, and its analysis is curious and important. Scheele,[a] Fourcroy,[b] and Vauquelin, Parmentier and Deyeux,[c] and many others have given particular attention to this subject, and from their united labours the following general account of its properties may be given.

Milk is a white opake fluid, varying in hue from a yellowish to a blueish tint, of a soft somewhat unctuous feel, and a sweetish and grateful taste. It frequently is altered in taste and smell and sometimes too in colour, by the nature of the aliment which the animal takes. The specific gravity of milk varies according to the animal that produces it, the food, and other circumstances. The gravity of cows milk is about 1.0203 according to Brisson, and this is the lightest next to human milk. Sheeps milk, which is heavy, weighs 1.0409.

The chemical composition of this fluid is the same in all animals, as far as has been examined, that is, all milks consist of the same substances in intimate combination, but the relative proportion of these substances is probably not the same in any two animals, and is so remarkably different in some, as to be obvious to common observers. In a general view milk may be said to be composed of the following ingredients.

1. Of the caseous or curdy matter, which is separable from milk by various means, and particularly by *rennet*, and which when collected and condensed by pressure forms cheese.

2. Of a true animal oil, butter, which is separable from the cream chiefly by agitation.

3. Of a sweet watery fluid, the serum or whey, which generally contains a good deal of the two former ingredients dissolved, and also holds a quantity of saccharine matter, of animal jelly, of muriat of soda, and potash, and some phosphats.

The further analysis of these three substances will be presently mentioned.

Milk when moderately heated swells and froths considerably, and at about 200° of heat it boils. At the same time there forms on the surface a tough dry pellicle, which when removed is succeeded by another, and so on successively. This skin is the same as the *curd* or caseous matter obtained by the common means, and if the process is continued for a great length of time, all the curd may be separated in this form, and a watery liquid alone will remain.

If milk is evaporated to dryness there remains a solid yellowish extract, known abroad by the name *franchipane*, and formerly used in medicine. If the vapour distilled from boiling milk be condensed in a proper receiver, it forms a clear liquor of a faintish taste, which after long standing becomes muddy and putrefies.

The coagulation of milk is one of the most important changes which it undergoes, and is effected by a variety of methods. All the acids coagulate milk, alcohol and all vinous liquors do the same, and also several vegetables. But the speediest and most perfect coagulation is effected by *rennet*, or an infusion of the stomach of calves, pickled and salted, which is the substance used in making cheese. The gastric

[a] Essays. [b] Encyc. Meth. Art. Lait. [c] Journ. de Physique.

juice of all animals alfo produces the fame effect, and hence coagulation is the firft procefs in the natural digeftion of this fluid.

Coagulation is the moft convenient method of analyzing milk, and it is thereby refolved into two principal portions, the *coagulum* or *curd*, and the *whey*. The analyfis of each of thefe fubftances gives the following refults.

Whey prepared by rennet (which is on the whole the beft fubftance for coagulating milk for chemical analyfis) when filtered and clarified is a limpid yellowifh fluid, of a fweetifh and rather faline tafte, agreeable to moft palates. Its fpecific gravity is fomewhat lefs than that of the milk from which it is procured. Whey when gently evaporated to the confiftence of a fyrup and allowed to cool undifturbed, depofits a fingular cryftalline fweetifh matter called *fugar of milk*, which is prepared pretty largely in fome of the Swifs cantons, and is ufed for culinary and medicinal purpofes. To prepare it, frefh whey from fkimmed milk is boiled down to the thicknefs of fyrup, and then poured into earthen pots, where it folidifies and dries in the fun; this mafs which is brown and impure is refined by re-folution, clarification with white of egg, and another evaporation, after which it concretes into white rhomboidal cryftals.

Sugar of milk when pure is a white cryftalline fubftance, of a fweetifh and rather mawkifh tafte, foluble in four parts of boiling water and about twelve of cold. When ftrongly heated it turns brown, fwells up and exhales the ftrong pungent vapour of burnt fugar, and finally leaves a black coal holding about $\frac{1}{30}$ of its weight of falt, compofed according to Rouelle, of three parts muriat of potafh and one part carbonat of potafh.

Sugar of milk has been ufually thought to be the chief agent in the vinous fermentation, which milk is capable of affuming, but it has been fhewn by Fourcroy and Vauquelin that this is a miftake, fince during the procefs no fugar of milk is deftroyed, as much being found after as before fermentation. Neither is it capable of fermenting by itfelf when diffolved in water and mixed with leaven.

Sugar of milk when boiled with nitric acid repeatedly, is converted partly into oxalic acid and partly into a peculiar acid to which the term *Saccholactic Acid*, or *Acid of Sugar of Milk*, has been given. It was firft difcovered by the ingenious refearches of Scheele,[d] and has fince been found to be identic with the mucous acid. It is prepared by abftracting nitric acid repeatedly from fugar of milk, during which an opake white powder feparates firft, and on cooling a quantity of cryftals alfo forms. The former is the faccholactic acid, the latter is oxalic acid. The faccholactic acid is very fparingly foluble in hot water, and poffeffes very faint acid properties, but its acid nature cannot be doubted fince it reddens litmus, has a flightly four tafte, effervefces with chalk, and forms neutral falts with alkalies. It has been ftrongly fufpected to be the oxalic acid, whofe ufual properties are mafked by an intimate union with fome animal matter, but no fatisfactory experiments have confirmed this opinion. Its properties will be further noticed under the article Mucous Acid.

After the evaporated whey has depofited all its fugar of milk, the mother liquor is a brown vifcous fluid, which on cooling concretes into a tremulous jelly. It alfo contains moft of the faline parts of the milk, which may be obtained by diluting it with water and again evaporating judicioufly and ftopping the procefs at intervals to allow of the feparation of the falts. The moft abundant of thefe is muriat of potafh, which appears in fmall regular cubic cryftals. Phofphat of lime is alfo contained in ferum and feparates at laft, but it may be more immediately obtained by adding lime-water to the whey before evaporation, this earthy falt being thereby rendered infoluble, the lime-water neutralizing a fmall excefs of acid naturally exifting in milk which holds the phofphat in folution. Any of the alkalies will produce the fame effect. The above two falts, muriat of potafh and phofphat of lime alfo appear, on calcining the dry refidue of evaporated whey, and lixiviating with water, the heat having deftroyed the acid which held the phofphat of lime fufpended.

The phenomena attending the coagulation of milk by acids and by alcohol will be foon noticed, that by rennet is underftood at prefent.

The curd of milk prepared by rennet, to be chemically pure, fhould be made of fkimmed milk, otherwife it contains much of the butter and oily part. The confiftence of curd depends on a number of minute circumftances, being fometimes quite foft and gelatinous, fometimes firm and as it were knotty. It is much condenfed and hardened by heat. A long continued preffure is neceffary, in order to feparate entirely the adhering portion of whey. Curd (or cheefe) from fkimmed milk, when flowly dried in a moderate heat, becomes hard, brittle,

[d] Effays.

and tranſparent like horn, which may be ſeen in ſome of the moſt ordinary cheeſes as prepared for food. Whilſt it retains its flexibility it is extremely tough and tenacious, and when heated it draws out into long ſtrings. If the heat becomes ſcorching it melts, takes fire and burns with flame, ſmoke, and a fetid ammoniacal ſmell. When diſtilled *per ſe* it alſo yields much ammonia, a fetid oil, much ſulphuretted and carburetted hydrogen, and a denſe ſaline coal from which muriat of potaſh may be obtained by lixiviation. Curd alſo contains much of the phoſphat of lime of the milk, provided the milk has not ſtood long enough to ſour and generate an acid which would keep this earthy ſalt ſuſpended. And, when dry and horny, it will keep to an indefinite time in a dry air without change, but if ſoft and not well preſſed, the whey which it contains becomes ſour, and the acid itſelf in a few days is covered with a white mould, gives out a moſt offenſive ſmell, and ſlowly putrefies. But the ſpontaneous decompoſition of cheeſe is very ſlow.

Curd is inſoluble in water, but when long kept under cold water, it is changed to a ſoft fatty matter, conſiderably different from the original ſubſtance. Cauſtic alkali diſſolves curd very readily, particularly if heated, and it may be again precipitated by acids. Some ammonia is diſengaged during the ſolution. Ammonia alſo acts on curd with equal rapidity. Quicklime, curds and water, intimately united by beating, form a ſtiff paſte of extreme tenacity, which ſoon acquires a ſtrong hardneſs and is often uſed as a very firm cement.

From all the properties of pure curd it appears to bear the ſtrongeſt analogy with the white of egg, as Scheele obſerves, and it may be conſidered as nearly pure albumen, but mixed with a certain portion of phoſphat of lime and a few other ſaline matters. Rouelle compared it to the gluten of wheat, which is alſo a juſt compariſon, ſince there is alſo ſcarcely any aſcertainable difference between pure gluten and pure albumen when each is in a condenſed coagulated ſtate. The effect of acids upon curd will be preſently noticed.

Butter, or the oily part of milk, is well known to be prepared from cream by long agitation. New milk is perfectly homogenous, but on ſtanding for ſome hours at reſt it throws up a thick yellowiſh-white cream, unctuous to the touch, and of a very bland agreeable flavour. In the proceſs of churning, the cream ſeparates viſibly into two ſubſtances, the butter which collects in a maſs, and a thick white liquid, the buttermilk as it is called, and whey, and ſtill retains a little of the butter.

Butter is much more eaſily made from ſtale than from freſh cream, probably owing to the ſpontaneous change which cream undergoes by keeping, and the evolution of an acid. Butter often varies in colour, being of every ſhade from a faint yellowiſh-white to a deep yellow, but the cauſe of this variation is not very apparent. The action of the atmoſphere has been thought by ſome to be concerned in the ſeparation of cream from milk, and of butter from cream, but nothing in the leaſt degree ſatisfactory has been brought in ſupport of this opinion, and it is certain that agitation alone in a corked bottle, will perfectly ſeparate butter from cream.

Freſh butter melts at about 98°, and when kept for ſome time melted, a ſmall quantity of ſerum and curd ſeparate from it. The butter becomes thereby more tranſparent, but has acquired a leſs pleaſant taſte. Butter when diſtilled *per ſe*, firſt gives over ſome water holding ſebacic acid, after which the greater part of the butter riſes with a pungent unpleaſant ſmell, and fixes in the receiver into a concrete empyreumatic greaſe. A further diſtillation of this greaſe gives a finer and more volatile oil than at firſt, and other products ſimilar to thoſe of the animal oils, as will be further mentioned under the article OIL. Butter when long kept becomes exceſſively fetid and rancid, but this is in a great meaſure prevented by ſalting. Alkalies diſſolve it with eaſe into a perfect ſoap.

On the whole, butter may be conſidered as moſt reſembling the animal oils, but intimately combined with a ſmall portion of the curd and whey and other parts of the milk, from which probably it can never be ſeparated without total diſorganization; and indeed as milk is a natural emulſion elaborated in the veſſels of the animal, the combination of its parts appears throughout to be ſo cloſe that it is ſcarcely in the power of art to break it intirely. Hence it is that we find the whey to retain almoſt to the laſt ſome of the curd and oil; the curd to be almoſt inſeparable from the laſt portions of the whey and butter (to which much of the varieties of cheeſe is to be attributed) and ſome of the curd and whey to remain in the compoſition of butter through every proceſs.

We proceed to deſcribe the effect of acids upon milk, and the ſpontaneous coagulation of milk by the acid which is generated in it by keeping for a certain length of time.

All acids readily curdle milk, and as appears from the experiments of Scheele, confirmed by

thoſe of Meſſrs. Fourcroy and Vauquelin,[e] the coagulum thus formed conſiſts of the curd united with a portion of the acid employed, inſomuch that if no more acid be uſed than is barely neceſſary, the whey ſhews no marks of acidity. The curd obtained by mineral acids (according to Scheele) is ſoluble in an exceſs of the acid, but not that produced by vegetable acids. If milk be previouſly mixed with ten parts of water, no curd is obtained by mineral acids, hence the cauſe of coagulation of undiluted milk in this caſe is, that the curd and acid together form a compound which requires for its ſolution much more water than the milk contains.

When milk is kept in a warm place it is known to grow ſour and thick in about two days, according to the temperature. This ſourneſs daily increaſes, and is the ſtrongeſt when about a fortnight has elapſed, and it then conſiſts of a ſoft curd, acid and ſomewhat nauſeous to the taſte, and of whey highly ſour and whitiſh. A ſtrong acid is therefore generated in the proceſs which was firſt accurately examined by Scheele, who diſcovered that the acid differed from any other then known, and to which he gave the name of *Lactic Acid*. It was thus prepared by this excellent chemiſt: the ſour whey was filtered and evaporated till only one-eighth remained. Some curd was ſeparated in the proceſs, which being removed by filtration the acid liquor was ſaturated with lime-water, by which a white precipitate of phoſphat of lime fell down and was removed. To the clear liquor (conſiſting of the peculiar acid and lime and ſome mucilaginous matter) juſt enough of oxalic acid was added to engage and precipitate the lime, which left the acid of the milk free in the liquor. This was then evaporated to the conſiſtence of honey, and ſtrong alcohol added, which diſſolved only the acid, leaving behind the ſugar of milk and other ſubſtances contained in the whey. The alcoholic ſolution was then diluted with water, and the alcohol diſtilled off, which finally left the lactic acid in a liquid ſtate in the retort as pure as it can ever be obtained.

The lactic acid is deſcribed by Scheele to have the following properties: evaporated to a thick conſiſtence it gives no cryſtals, and when dried it readily deliqueſces again; when diſtilled it yields water, a weak acid like the tartareous, and afterwards empyreumatic oil, acid, and an inflammable air: ſaturated with potaſh it gives a deliqueſcent ſalt, ſoluble in alcohol, and with ſoda an uncryſtallizable ſalt, but alſo ſoluble in alcohol. With ammonia and the earths it forms deliqueſcent ſalts. It diſſolves iron and zinc, giving out inflammable air, and acts upon ſome of the other metals.

It cannot be formed directly from ſour whey by diſtillation, for on making the trial, only a ſlightly acidulous water riſes in a boiling heat, and by far the greater part of the acid remains behind in the retort. From its very cloſe reſemblance to vinegar, the diſcoverer conſiders it as an imperfect acetous acid, containing the materials of this acid, but wanting the vinous fermentation to be compleatly elaborated. In proof of this opinion he adds, that if to a kanne (lb $5\frac{1}{4}$ Engliſh) of milk be added four, or five ſpoonfuls of brandy, and the veſſel containing it, well corked, be expoſed to warmth with occaſional exit of the vapour generated, the whole of the whey will be changed into good vinegar.

Some later experiments have been made by Meſſrs. Fourcroy and Vauquelin, on ſoured milk, particularly with a view to determine the exact nature of Scheele's lactic acid, whereby it appears moſt probable that this acid is in fact acetous acid, but with its perfect character ſomewhat maſked by holding in ſolution a quantity of animal matter. We ſhall in a few words give the leading particulars of theſe valuable experiments, as they alſo throw ſome further light on the general analyſis of milk.

A quantity of milk was let to ſtand in a warm place for five days till it was quite ſour, after which the cream was carefully ſkimmed off and the remainder was heated to compleat the ſeparation of the curd from the whey. The curd well waſhed and preſſed dried into a flexible tranſparent horny ſubſtance, which when burnt to aſhes left a ſmall quantity of aſh (much leſs than when the curd is prepared from ſweet milk by rennet) moſt of which was phoſphat of lime.

The ſour whey was then carefully analyzed in the following manner. Lime-water was added as long as any precipitate fell down, which latter was collected and calcined, during which it gave out ammoniacal oily vapours, ſhewing the preſence of an animal matter. The calcined reſidue treated with ſulphuric acid gave ſulphat of lime, and phoſphoric acid was found in the ſupernatant liquor. By evaporation of this laſt to dryneſs and calcination, the reſidue aſſumed a red colour, and on adding water part was diſſolved and a red oxyd of iron was left. The ſolution depoſited by reſt ſome cryſtals of ſulphat of magneſia. Hence it appears that the

[e] Encyc. Meth. Art. Lait.

whey contained phosphat of lime and of magnesia along with some iron.

The whey, after the precipitate with lime-water had been removed, was then treated with oxalic acid and evaporated in a retort to a small bulk in the manner described by Scheele. The fluid expelled by evaporation was collected and found to be slightly sour and somewhat empyreumatic, but the liquor which remained in the retort was reddish-brown, and very sour, and contained by far the greater part of the lactic acid. To this liquor which was as thick as syrup, a large quantity of strong alcohol was added, which caused the separation of a brown thick viscous matter, not the least acid, soluble in water, giving a precipitate with galls, and affording carbonat of ammonia by distillation. By standing it deposited some sugar of milk. It therefore consisted of sugar of milk apparently unaltered by the souring of the milk, and of a peculiar animal matter. The alcoholic solution was highly acid and of a dark red, and by the frequent boiling it had acquired a dark colour and empyreumatic smell. The alcohol being distilled off and water added, the liquor was repeatedly treated with sulphuric acid and distilled, whereby, on the one hand, there was a constant separation of a bituminous matter, and on the other a portion of perfect acetous acid was constantly obtained by distillation. By this ingenious method the whole was resolved into acetous acid and into a peculiar bituminous matter dissolved therein, and to which the acid owes those properties by which it differs from common acetous acid.

From these and other researches by the same chemists, it appears therefore that there is no such distinct acid as the *lactic* of Scheele, but that it is acetous acid holding in solution a quantity of animal matter, to which it owes the property of giving a brown precipitate with galls, a yellowish-grey with nitrat of mercury, and a brown with acetite of lead; and from the same cause also it gradually darkens in colour and deposits a brown matter by evaporation. The above chemists also observe that an acid precisely similar to the lactic is produced by dissolving gluten in vinegar, by fermenting together a mixture of sugar, water and gluten, and it also is the same as the *sours* procured in starch-making by the fermentation of wheat flour and water.

The lactic acid diluted with water, and long kept in a warm place, gradually loses the whole of its acidity, deposits a brown matter, acquires a fetid smell, and on adding lime gives out ammoniacal vapours. The same effects are also produced by a solution of gluten in vinegar.

The nature of this animal matter which by uniting with acetous acid forms the lactic acid of Scheele, is not precisely ascertained. It is probably the chief cause of that spontaneous change by which milk turns sour, and largely contributes to form the acetous acid which is then generated, but it is not totally decomposed by the acid fermentation, since the acetous acid when formed dissolves a portion of it for a time, and thus protects it from further change. This matter appears also to differ from the curd, since on the one hand, when deposited from the lactic acid by evaporation, it shews no resemblance to curd; and on the other hand a solution of curd in vinegar will not be discoloured by evaporation, nor can it be brought to deposit any substance similar to the other. It is most probable therefore that *gluten* must be added to the constituent parts of milk.

Milk is susceptible of the vinous fermentation so as to be made to yield an ardent spirit by subsequent distillation, but it is not very easy to ferment milk, and it always turns sour at the same time. The Tartars and other Asiatic nations have been from time immemorial in the habit of preparing an intoxicating liquor from mare's milk. This is called *koumiss*, and the process is thus given by Dr. Grieve.[e] Take any quantity of mare's milk, dilute it with a sixth of water, pour it into a wooden vessel, and add as a ferment about one-eighth of very sour milk, or better, of old koumiss, cover the vessel with a thick cloth and keep it in a moderate temperature. After standing twenty-four hours, a thick coagulum rises to the top, which must be well mixed by beating. After reposing for another day, it is again stirred till it becomes quite homogeneous, and in this state it forms the koumiss, which has an agreeable sweetish acescent taste.

Milk in the state of koumiss does not easily change by keeping. By distillation it yields a considerable quantity of alcohol, as much (according to Pallas) as one-third of its bulk. The entire milk appears essential to the production of ardent spirit, as well as frequent agitation to mix the constituent parts which the acid has caused to separate.

The sugar of milk (which is never absent) will naturally be looked to as the source of the alcohol and the cause of the vinous fermentation. But Messrs. Fourcroy and Vauquelin deny this

[e] Memoirs R. Soc. of Edinb. for 1788

to be the cafe, firft, becaufe pure fugar of milk mixed with water and leaven, and expofed to moderate heat will not ferment as common fugar does, nor yield any alcohol: and fecondly, becaufe nearly as much fugar of milk is found in whey thoroughly foured by keeping, as in frefh milk. But as the above chemifts were not able to procure any alcohol from milk foured in the common way, it is obvious that it cannot be at all inferred from thence that the fugar of milk is not decompofed in the procefs that *does* form alcohol; but only that this fubftance does not appear active in the formation of the lactic (that is, the acetous) acid. Neither does it at all follow that fugar of milk is not decompofed in entire milk, becaufe when previoufly feparated from milk it cannot then be made readily to ferment. It is probable on the other hand that both the acetous and the vinous fermentations are going on at the fame time in milk whilft converting into koumifs, and that the materials for thefe two proceffes are not the fame as in common vinous fermentation (the acetous being there chiefly a continuation of the vinous procefs), but are, partly at leaft, diftinct, the gluten contributing chiefly to the acetous, and the fugar of milk to the vinous.

Though the milk of different animals is found to be effentially the fame in the number and chemical nature of the feveral ingredients (as far as has been examined), yet a very confiderable difference is found in the proportion of thefe fubftances and in fome of their fenfible properties. The experiments of Parmentier are particularly curious on this fubject. The kinds of milk that he examined were, firft, cow's milk as a ftandard, to which were compared the following, viz. woman's, affes', goat's, ewe's and mare's milk.

Woman's milk is fweeter than cow's, and thinner, but it is of all others, that which varies moft according to the ftate of body, conftitution, age, &c. of the perfon whence it is drawn. The cream is on the whole more copious than of common cow's milk, but it differs peculiarly in this, that neither agitation nor any other known means will entirely feparate the butter; the utmoft effect of thefe means being only to give the whole cream fomewhat of an unctuous confiftence, without effecting any feparation into butter, curd, and whey.

Human milk alfo depofits part of its curd by mere reft, which is found fticking to the fides of the veffel which holds it. Though fweeter to the tafte than cow's milk it does not contain fenfibly more fugar.

Affes' milk more refembles the human than any other. The cream is in fmall quantity, by agitation it gives a butter which is foft, white, and nearly taftelefs. It foon becomes very rancid owing probably to its retaining a portion of the acid. By ftanding, it depofits much of the curd even before it becomes four.

Goat's milk is very thick, yellowifh, and pleafantly flavoured. It is fomewhat denfer than cow's milk. The cream is remarkably thick and unctuous, and will keep a long time without growing four or fenfibly changing. By agitation it gives a very firm, folid, and white butter, to appearance very free from all admixture. This milk alfo abounds in curd, fo that when heated, a much thicker pellicle rifes, and when coagulated by any of the ufual methods the curd is fo abundant that the whey is with difficulty feparable. It is alfo of a very gelatinous denfe confiftence. The fugar of milk is fmall in quantity, but feparates with eafe.

Sheep's milk refembles cow's very clofely in tafte and appearance. It yields abundance of cream, which by churning affords much butter, but which always remains very foft. The quantity of curd is remarkably large, and it has a very fat and unctuous appearance, and a tafte which is peculiar to it, and is always very diftinguifhable in ewe-milk cheefe.

Mare's milk is thin and infipid, and does not coagulate with vinegar. It is remarkable for the fmall quantity of cream which it gives and the extreme difficulty of feparating the butter from it by agitation. The whey contains fulphat of lime, which has not been found in any other milk.

The above-mentioned fpecies of milk all refemble each other effentially in the number and general chemical nature of the ingredients, but great diverfity appears in their refpective proportion, and apparently in the mode of mixture. Thus with regard to the cream, cow's and fheep's milk yield it eafily by repofe, its confiftence is greater than in the others, and the butter feparates more perfectly. There is an equal difference in the confiftence of the curd, that from cow's and fheep's milk being denfe, and readily feparating by the ufual coagulating fubftances, but the curd from afs's and mare's milk always remains thin, and almoft of a creamy confiftence. The only general agreement which the authors of thefe experiments have been able to make on this fubject, is that where the curd is tough and gelatinous, the butter is readily feparable from the cream, and all the conftituent parts of the milk are more eafily obtained by chemical means.

MINERALIZER is any ſubſtance found in natural combination with a metal. Thus lead is ſaid to be *mineralized* by ſulphur, when combined with it in the native ſulphuret or galena.

MINIUM. See Lead, *(Oxyds of)*.

MISPICKEL. See Arsenic, *(Ores of)*.

MOONSTONE or ADULARIA. See Felspar.

MOORSTONE. See Granite.

MORDANT. See Dying, *(Art of)*.

MORTAR. See Cements calcareous.

MORTAR (Chemical inſtrument). See the Appendix.

MOSAIC GOLD. See Tin.

MOTHER OF PEARL. See Shell.

MOTHER-WATER is the uncryſtallizable reſidue of a compound ſaline ſolution. For further particulars ſee the article Crystallization.

MOLYBDENA. *Molybdan*, Germ. *Molybdène*, Fr.

Molybdena is a metal of a greyiſh white colour, in the form of brittle infuſible grains. It is convertible to a yellowiſh white oxyd by expoſure to the air at a red heat, or by the action of nitric acid.

§ 1. *Ores of Molybdena*.

Sp. 1. Molybdena, or Sulphuret of Molybdena. *Waſſerbley*, Wern. *Molybdène ſulfuré*, Broch.

Its colour is nearly that of freſh cut metallic lead. It occurs maſſive, diſſeminated, and rarely cryſtallized. Its primitive figure is a ſtrait priſm with rhomboidal baſes, the alternate angles of which meaſure 60° and 120°. It alſo occurs in ſhort regular hexahedral priſms, the baſes of which are ſometimes terminated by ſhort hexahedral pyramids: ſometimes alſo the intervening priſm is wanting, the pyramids at the ſame time being deeply truncated. The cryſtals are ſmall or middle-ſized, and are always implanted. Internally it is more or leſs ſhining with a metallic luſtre; its fracture is curved and ſometimes radiating lamellar. Its fragments are indeterminate and blunt edged, or in irregular laminæ. It occurs in granular diſtinct concretions. It is opake, ſtains the fingers, leaves ſhining traces when drawn over paper; is very ſoft and eaſily diviſible in the direction of its laminæ; is ſectile, eaſily frangible, flexible but not elaſtic, and is unctuous to the touch. Sp. gr. 4.56 to 4.73.

It is infuſible before the blowpipe but exhales a ſulphureous odour: at a very high heat it melts, gives out white fumes and burns with a blue flame; by a long continuance of the heat it is converted into a maſs of yellow and delicate needleform cryſtals.

Its conſtituent parts are probably ſulphur and metallic molybdena, but the proportions have not yet been aſcertained with much accuracy. According to Pelletier it conſiſts of

Molybdic acid - -	45
Sulphur - - - -	55
	100

Some of the early experiments of Klaproth induced him to ſtate its ingredients at

Molybdena - - -	60
Sulphur - - - -	40
	100

Laſtly, Lampadius has analyzed this mineral, and finds it to be compoſed of

Molybdena - - -	76
Sulphur - - - -	23
Iron - - - - -	1
	100

Molybdena occurs diſſeminated or in veins, in primitive mountains accompanied by tinſtone, wolfram, quartz, mica, and rarely with native arſenic, heavy ſpar, fluor ſpar, and topaz. It is found at Hitterdahl and Arendahl in Norway; Baſtnaes in Sweden; Altenberg and Zinwald in Saxony; Mont Blanc in Switzerland.

Sp. 2. Molybdat of Lead. Yellow Leadſpar. *Gelbes Bleyerz*, Wern. *Plomb jaune*, Broch. *Plomb Molybdaté*, Hauy.

The uſual colour of this mineral is wax yellow, which paſſes either to lemon or orange-yellow or ſometimes to a dirty honey-yellow. It occurs for the moſt part cryſtallized, very rarely maſſive. Its primitive figure is a rectangular octohedron with iſoſceles triangular faces: the incidence of the faces of one pyramid on the correſponding ones of the other is 76° 40′. The other varieties of form that it exhibits are,

1. The primitive octohedron with either all the ſolid angles or only the two vertical ones replaced by quadrilateral priſms.

2. The ſame as the preceding, with the lateral edges of the pyramids replaced by narrow triangular faces, and therefore the four ſecondary faces round the common baſe of the pyramids are not quadrilateral but hexagonal planes.

3. A rectangular parallelepiped ſometimes ſo thin as to be tabular, ſometimes approaching to the cube.

4. The cuboidal preceding variety with its terminal edges replaced by rather narrow quadrilateral planes.

5. An eight-fided table.

6. A twelve-fided table.

The tabular varieties are for the moft part broad and thin and interfect each other in various directions, thus giving the whole mafs a cellular appearance. Externally it is fmooth and fhining; internally it is gliftening and refinous. Its fracture is fmall grained uneven, paffing into imperfectly lamellar and fmall conchoidal. Its fragments are indeterminately angular, moderately fharp-edged. It is tranflucent, foft, rather brittle, and eafily frangible. Sp. gr. 5.09.

Before the blowpipe it decrepitates and then fufes into a dark grey mafs in which globules of reduced lead are perceptible; with a fmall proportion of borax it forms a brownifh yellow globule, but if a larger quantity of borax is employed the refult is a blue or greenifh blue glafs.

It has been analyfed by Klaproth, Hatchett, and Macquart, with the following refults.

	Klapr.	Hatch.	Macq.
Molybdic acid	34.25	38.	28.
Oxyd of lead	64.42	58.4	63.5
Oxyd of iron	0	2.08	0
Carbonat of lime	0	0	4.5
Silex	0	0.28	4.
	98.67	98.76	100.0

This mineral was firft met with at Villach in Carinthia, in compact lime-ftone accompanied by calcareous fpar, molybdena, galena and other lead ores, calamine, blende and fluor fpar. It has fince been found at Freudenftein in Saxony, Annaberg in Auftria, and Reczbanya in Hungary.

§ 2. *Affay and Analyfis.*

The moft ufual method of decompofing the fulphuret of molybdena is by detonation with nitre; but by this means the molybdic acid becomes fo intimately combined with potafh as to render it extremely difficult by fubfequent operations to obtain it pure. The beft mode of proceeding therefore appears to be the following.

a. To one part of finely pulverized molybdena add four or five parts of moderately diluted nitric acid, and diftil the mixture nearly to drynefs; then return the contents of the receiver into the retort, add fome more nitric acid and proceed a fecond time to diftillation; repeat this for three or four times till the infoluble matter in the retort is as white as chalk. Now pour off the fupernatant fluid and wafh the white matter repeatedly in warm water, adding the wafhings to the other fluid.

b. Evaporate the refidual fluid to a moderate degree of concentration, and then pour in ammonia; the firft portions will occafion a precipitation, but by adding more ammonia and affifting the procefs by a gentle warmth, the whole precipitate will be re-diffolved; then drop in ftrong nitric acid to compleat faturation of the alkali, and a white precipitate will fall down, which is to be feparated by the filter and wafhed in warm water.

c. The refidual fluid with the wafhings being mixed together now contains ammonia combined with nitric and fulphuric acids, the latter of which arifes from the oxygenation of the fulphur in the ore. Nitrat of barytes being dropped in, a precipitation of fulphated barytes takes place, from the amount of which the quantity of fulphur in the ore is readily inferred.

d. The white matter obtained in proceffes *a* and *b*, which is molybdic acid with a little oxyd of iron, muft now be diffolved in ftrong fulphuric acid, and the folution fubfequently diluted with 16 times its weight of water; ammonia being now cautioufly added to perfect faturation the iron will gradually fall down in the ftate of yellow oxyd.

e. The clear liquor of the preceding procefs being evaporated to drynefs, the falt thus procured is to be ftrongly heated in a glafs veffel till all the fulphat of ammonia is expelled; what remains behind is a black bliftered mafs, which by abftraction with nitric acid is converted into a yellow powder, which is pure molybdic acid.

The only material objection to this method of analyfis is that the molybdena exifts in its metallic ftate in the ore, but is obtained in the analyfis in the ftate of acid; and as the amount of oxygen in molybdic acid has not yet been afcertained, this analyfis is at beft only an approximation to a true knowledge of the ingredients of this ore, fo long as we remain ignorant of the compofition of molybdic acid.

The molybdat of lead has been analyfed fatisfactorily by Mr. Hatchett[a] in the following manner.

a. The ore, previoufly reduced to fine powder, was digefted three feveral times at a ftrong heat with fulphuric acid, which diffolved out

[a] Phil. Tranf. for 1796 p. 320.

the iron and molybdic acid, leaving the ſilex and lead (in the ſtate of ſulphat) behind.

b. The fluid was ſubjected to the ſame proceſs as that deſcribed in paragraphs *d* and *e* of the preceding analyſis, by which the oxyd of iron and molybdic acid were ſeparated from each other and obtained in a ſtate of purity.

c. The white reſidue of proceſs *a* was boiled with carbonat of ſoda, and being afterwards well edulcorated was digeſted in very dilute nitric acid; the carbonat of lead was diſſolved with effervеſcence, leaving behind the ſilex in the form of a white powder.

d. The nitrat of lead was decompoſed by ſulphuric acid, and after the ſulphat of lead had been thus ſeparated, the reſidual fluid, after ſaturation with ammonia, depoſited a minute portion of oxyd of iron.

§. 3. *Reduction of Ores.—Phyſical properties of Reguline Molybdena.*

As molybdena is a metal that has not hitherto been applied to any uſe, ſo there has been no attempt in the great way to reduce its ores. The compleat decompoſition of the acid or oxyd of this metal, has however been undertaken by various chemiſts, and for the moſt part with but little ſucceſs. The chief cauſe of failure ſeems to have been that the ſubſtance operated on, inſtead of being the pure metallic acid, has alſo contained a portion of fixed alkali, which by its affinity for the acid moſt powerfully oppoſes its deoxydation. The method that as yet has been attended with the moſt ſatisfactory reſults is that publiſhed by Hielm. The acid being made into a paſte with linſeed oil, is to be expoſed to a ſtrong heat in a covered crucible; being then withdrawn from the fire, the black maſs is to be pulverized and again mixed with oil, and torrefied as before; by repeating this two or three times the molybdena is compleatly reduced, and aſſumes its proper metallic luſtre. It appears highly probable that the method which has been ſucceſsfully practiſed in the reduction of tunſtic acid, would be equally efficacious with the molybdic acid. It is the following. Let the pure molybdic acid be combined with as much ammonia as poſſible, and then expoſed to an intenſe heat in a crucible lined with charcoal: the ammonia would be decompoſed, and its hydrogenous baſe together with the charcoal, would probably carry off the whole of the oxygen from the metal.

Molybdena in the only ſtate in which it has hitherto been procured, is a very looſely adhering aggregate of minute grains of a yellowiſh white colour and metallic luſtre. When recently broken it exhibits a greyiſh white colour. It is hard, very brittle, and difficultly fuſible. Sp. gr. 7.5.

§. 4. *Chemical Properties.*

Moſt of the chemical properties of molybdena have been aſcertained by experiments on the native ſulphuret; theſe we ſhall firſt mention, and then notice thoſe of which the pure regulus has been the ſubject.

If the native *Sulphuret of Molybdena* is expoſed to the continued action of a low red heat with acceſs of air, the ſulphur is burnt off, and the metal is changed to a greyiſh white oxyd, of which a part is volatilized in the form of a white vapour. If the ſame experiment is performed in a wide earthenware tube paſſed through a furnace, and heated conſiderably higher than in the former caſe, the ſulphur is burnt off, and the metal in proportion as it is oxydated aſſumes the ſtate of vapour, which condenſes in the cooler parts of the tube into ſlender needleform cryſtals of a brilliant ſilvery white colour, exceedingly ſimilar in external appearance to the argentine flowers of antimony. Theſe cryſtals have a ſour metallic taſte and are molybdic acid.

Nitric acid by repeated digeſtion on ſulphuret of molybdena is itſelf decompoſed, and converts both the ſulphur and metal into acids; the latter aſſumes the form of very minute white cryſtals: by expoſing the maſs to a heat below redneſs in an earthen crucible, the laſt portions of nitric acid and nearly the whole of the ſulphuric are driven off, and by ſubſequent waſhing in water, the remainder of the ſulphuric acid is got rid of, ſo that the molybdic acid remains pure. Oxymuriatic acid has a ſimilar effect to that of the nitric, but no other acid except the arſénic exerts any action on molybdena. When this latter acid in a ſolid ſtate is ſtrongly heated in contact with molybdena, a quantity of ſulphureous acid is produced, the arſénic acid is converted into white oxyd and orpiment, a part alſo being often reduced to the metallic ſtate; what remains in the retort is a black ſhining maſs apparently conſiſting of reguline molybdena: hence it may be inferred that the action of the arſénic acid is confined merely to the ſulphureous part of the ore.[b]

Cauſtic fixed alkali unites by fuſion with molybdena into an uniform maſs of a greeniſh colour, extremely deliqueſcent and totally ſoluble in

[b] Pelletier Mem. i. 197.

water; the solution exhales an hepatic odour, and on the addition of muriatic acid a copious black precipitate falls down without any sulphuretted hydrogen being disengaged. This black matter is considered by chemists as regenerated sulphuret of molybdena, but from the circumstances of the experiment appears to be a hydroguretted sulphuret.

If nitre and molybdena in the proportion of two parts of the former to one of the latter be detonated together, there will be produced sulphat of potash and molybdat of potash with excess of base, which is often mistaken for pure molybdic acid.

The facts hitherto observed concerning *reguline molybdena* are but few in number and exactly analogous to those that have been just now mentioned relating to the sulphuret. It is oxydable by continued exposure to air at a red heat; it decomposes nitric and oxymuriatic acids, and is itself at the same time oxydated and acidified. When mixed with caustic fixed alkali and fused, an inflammable gas is given out, the metal is acidified and combines with the alkali. When mixed with sulphur and exposed to a low red heat in a retort, part of the sulphur is volatilized and the residue combines with the metal into a substance exactly resembling the native sulphuret. It is also capable of uniting with phosphorus. It forms friable alloys with iron, copper, and silver, the properties of which have not yet been examined.

Molybdic acid, when prepared according to the method described in §. 2, is a lemon-yellow powder of the sp. gr. of 3.4: to the taste it is acid and metallic. When heated in a close vessel it melts, and on cooling concretes into a striated yellow mass; in an open vessel it is volatilized in the form of a white vapour, which as it deposits on cool surfaces crystallizes in silvery needles. With borax it forms a brownish-yellow glass, and with microcosmic salt a glass, which in proportion to the acid employed varies from greenish to sky blue.

It is soluble in about 1000 times its weight of distilled water; the solution is of a pale yellow colour, with scarcely any perceptible flavour; but it reddens litmus paper. Nitrat of lead is decomposed by it, and a yellow insoluble precipitate falls down which is molybdat of lead.

Nitrat of barytes is rendered slightly turbid by it; but nitrat of lime undergoes no change. Prussiat of potash produces no visible effect, but if a few drops of any of the mineral acids are added, a copious brown precipitate of prussiated molybdena immediately falls down. With muriat of tin it immediately assumes a beautiful deep blue tinge. The solution receives a similar but fainter tinge by being boiled with filings of any of the easily oxydable metals.[c]

Concentrated sulphuric acid dissolves at a boiling heat a considerable quantity of molybdic acid: the solution while hot is colourless, but as it cools acquires a fine blue colour and becomes thick. From this compound, when diluted with water, prussiat of potash throws down a reddish-brown precipitate. Muriat of tin produces no effect upon it. When distilled to dryness, the sulphuric acid passes over and the molybdic acid remains pure. If to this sulphuric solution caustic soda be added to saturation, the blue colour is rendered more intense and the molybdic acid seems to unite with the alkali in two different proportions; the neutral molybdat of soda remains in solution, and a white precipitate falls down, consisting apparently of soda with excess of molybdic acid. The solution is not decomposable by prussiated potash, but is changed to a deep blue by muriat of tin. If however the solution be slightly acidulated, muriat of tin produces no change, but prussiat of potash occasions a copious brown precipitate.

Molybdic acid when boiled with strong muriatic acid is dissolved in considerable proportion forming a yellowish-green fluid. In its habitudes with muriat of tin and prussiat of potash, both before and after saturation with alkali, it exactly resembles the sulphuric solution already described. When distilled to dryness, the muriatic acid passes over oxygenated, and the residue in the retort is of a greyish blue colour: some white and bluish flowers commonly rise at the same time; they are considerably deliquescent and consist of molybdic oxyd with muriatic acid.

Nitric acid has no effect on molybdic acid.

If a solution of carbonat of potash is boiled with molybdic acid, carbonic acid is disengaged and the molybdic acid is dissolved; in proportion however as this goes on, a white flocculent matter falls down. The liquor contains alkaline molybdat of potash, which is not decomposed by prussiat of potash or changed to a blue colour by muriat of tin, except the excess of alkali is somewhat more than neutralized by the addition of some of the mineral acids. The white flocculent precipitate is probably acidulous molybdat of potash, which by digestion in

[c] Scheele's Ess. p. 233.

nitric acid is reconverted into the yellow acid in consequence of the loss of the greatest part, if not the whole, of its alkali.

If carbonat of soda and molybdic acid are boiled together, a disengagement of carbonic acid takes place, and, in proportion as the molybdic acid is dissolved, a white flocculent precipitate is deposited. The action of muriat of tin and prussiat of potash upon the clear liquor is precisely the same in this case as in the preceding. By gentle evaporation the alkaline molybdat of soda may be made to crystallize in four-sided tables.

Molybdic acid is taken up in greater quantity by carbonat of ammonia than by the fixed alkalies, and scarcely any precipitate falls during the solution. It is affected by prussiat of potash and muriat of tin, in the same manner as the preceding salts. By distillation to dryness the ammonia is decomposed, and the molybdic acid is in consequence so far deoxygenated as to be converted into a grey oxyd.

Molybdic acid appears to have a strong affinity for that portion of alkali, whether potash or soda, which is requisite for the constitution of the acidulous molybdat: hence it is that not only nitre but even sulphat of potash is in part decomposed by distillation at a full red heat with molybdic acid, a little nitrous acid in one case and sulphuric acid in the other passing over into the receiver. If muriat of soda is treated in the same manner, oxymuriatic acid is given out and a portion of the molybdic acid is converted to the blue oxyd. But if instead of the pure acid the acidulous molybdat (produced from the detonation of nitre with the sulphuret of molybdena) be employed, no decomposition of the above neutral salts will take place.

Molybdic acid is decomposable even in the moist way by hydrogen. For this purpose let a vial be filled with a solution of the acid in water and throw up hydrogen gas, till nearly half of the liquor is displaced, then cork the vial and shake it well; in a short time the dilute yellow colour of the solution will change to blue, thus indicating a deoxygenation of the acid.

Sulphur, charcoal, and other combustible substances also decompose the molybdic acid; when the former is made use of, part of the sulphur is converted into sulphureous acid, and the remainder combines with the reduced molybdena into a black matter perfectly analogous to the native sulphuret.

The different proportions of oxygen with which molybdena is capable of uniting have not hitherto been ascertained. According to Mr. Hatchett this metal has four distinct states of oxygenation: when at the highest it is of a yellow colour and is the pure molybdic acid; the next step of the descending series is the green oxyd or molybdenous acid produced by dissolving the yellow acid in muriatic acid: to this succeeds the blue oxyd produced by the action of muriat of tin on either of the two former; and last of all is the black oxyd formed by heating molybdic acid with charcoal, yet not so as entirely to bring it to the metallic state.

Neither the metal nor any of its preparations are made any use of.

MOUNTAIN BLUE. See COPPER. p. 321.

MOUNTAIN GREEN. See COPPER. p. 322.

MOUNTAIN CORK. See ASBEST.

MUCILAGE. *Der Schleime.* Germ.

Vegetable mucilage is contained in every plant that has been hitherto analyzed, in some parts more abundantly than in others, and the quantity also varies considerably according to the age and other circumstances of the vegetable. It appears to be one of the elementary vegetable constituents, and probably by its decomposition in the organs of the plant it is converted into other substances, since it often is extremely abundant in the earlier age of the plant, and lessens as other principles are elaborated.

The essential chemical properties which characterize mucilage, are the following: it is insipid, highly soluble in water, giving it a thick clammy appearance and feel, insoluble in alcohol, not coagulated by a boiling heat, not crystallizable, and after the watery solution has been evaporated to dryness it is again soluble in water without having undergone any material change.

These are the distinguishing properties of mucilage in its present state, to which it may be added that when pure and dissolved in water, it does not readily undergo any spontaneous change. After a while indeed it becomes mouldy and somewhat sour, but it is very slowly altered by this process. When heated to ignition it swells and softens, becomes yellow, brown, and black, and exhales a dense vapour which has a pungent acid smell, and burns with much flame, and a soft spongy coal is left.

Mucilage is sometimes found nearly pure, exsuding from the bark and twigs of many vegetables, by natural and artificial clefts, and hardening in the sun into brittle nearly transparent roundish lumps. In this state it may be called *Gum Mucilage.*

The purest of the gum-mucilages is Gum-Arabic or Senegal, which forms a very valuable article of commerce to the countries that yield

it. An inferior ſort of gum for the purpoſes of manufacture, but cloſely reſembling Gum-Arabic in every property, is that which exſudes from cracks in plumb, peach, pear, and other fruit trees, and has generally the colour of amber. Beſides theſe ſources of gum-mucilage there are many vegetables whoſe native juices ſo much abound with mucilage that a conſiderably pure and ſolid gum may be obtained by ſimple decoction of the plant and evaporation to dryneſs. Several of the lichens, the leaves of the comfrey and mullen, the root of the harebell, and the whole plant of the marſh-mallow, afford a good mucilage in this method.

We ſhall firſt give a ſhort account of the gathering of the Gum-Senegal,[a] before we proceed to the chemical properties of mucilage. The Gum-Arabic is obtained in a ſimilar manner, and Cairo and Alexandria were the principal marts for this gum, till the Dutch introduced the gum from Senegal into Europe, about the beginning of the ſeventeenth century, and which now ſupplies the greater part of the vaſt conſumption of this article.

The tree which yields this gum is a ſpecies of mimoſa, which grow abundantly on the ſands along the whole of the Barbary coaſt, and particularly about the river Senegal. There are ſeveral ſpecies, ſome of which yield a red aſtringent juice, which when inſpiſſated forms the *Catechu*, but others afford only a pure nearly colourleſs inſipid gum, which is the great article of commerce. Theſe trees are from 18 to 20 feet high, with thorny branches. The gum makes its appearance about the middle of November, when the ſoil has been thoroughly ſaturated with the periodical rains. The gummy juice is ſeen to ooze through the trunk and branches, and in about a fortnight it hardens into roundiſh drops of a yellowiſh-white, which are beautifully brilliant where they are broken off, and entirely ſo when held in the mouth for a ſhort time to diſſolve the outer ſurface. No clefts are made nor any artificial means uſed by the Moors to ſolicit the flow of the gum. The lumps of Gum-Senegal are uſually about the ſize of partridge eggs, and the harveſt continues about ſix weeks. The quantity annually ſold out of the Senegal country for European conſumption is about twelve hundred thouſand pounds weight.

This gum is alſo a very wholeſome and nutritious food, thouſands of the Moors ſupporting themſelves entirely upon it during the time of harveſt. About ſix ounces is ſufficient to ſupport a man for a day, and it is beſides mixed with milk, animal broths, and other victuals.

The Gum-Arabic, or that which comes directly from Egypt and the Levant, only differs from the Gum-Senegal in being of a lighter colour and in ſmaller lumps, and it is alſo ſomewhat more brittle. In all other reſpects the two reſemble each other perfectly. Its ſpecific gravity is about 1.45.

The uſes of this gum are very great and numerous. The greateſt conſumption of Gum Senegal is in furniſhing a thick viſcid fluid with which the different mordants are mixed in calico-printing, which has been more particularly deſcribed in the article *Dyeing*.

Another great uſe of Gum-Arabic is in giving a fine gloſs or glazing to ribbons and ſilks. For this purpoſe a thin ſolution is made, and the ſilk ſlightly bruſhed over with it, and when dry it leaves a very thin colourleſs varniſh, but readily waſhed off by water, whence the ſpotted appearance that a ſhower of rain gives to theſe articles. Gum-Arabic is alſo uſed as a clean, convenient, and pretty ſtrong cement for an infinite number of purpoſes where there is no riſk of moiſture. Its ready ſolubility in water and the length of time which the ſolution will keep without ſpoiling, render it highly valuable in the arts.

This gum is alſo employed in pharmacy as a very convenient way of rendering miſcible with water, oils, reſins, and other ſubſtances on which water alone has no action. The effect here is chiefly mechanical. The ſubſtance (olive oil for example) is to be well rubbed with about half its weight of a ſtrong ſolution of gum, and the watery liquid afterwards added by degrees and with conſtant rubbing, and by this method an opake emulſion is formed, in which the ſubſtances will remain mixed for many hours, nor will they again entirely ſeparate.

To obtain the gum-mucilage from thoſe vegetables that do not yield it by exſudation, recourſe muſt be had to boiling with water and evaporation. Theſe kinds of mucilage however will ſeldom anſwer as cements, as they will not ſufficiently harden by drying, and they are more liable to mould, and to become brown and coloured during the requiſite evaporation.

Lord Dundonald[b] has given the following directions for preparing the mucilage from the lichen. This plant is the common large-leaved moſs that grows ſo abundantly on foreſt and fruit trees, and in the North of Europe and America, it grows to the length of a foot or more, giving a nutritious food to deer and other

[a] Golberry's Travels in Africa.

[b] Phil. Mag. vol. x.

animals. The lichen has an outer skin, and below this a green resinous substance; and the remainder of the plant consists chiefly of gum and of fibrous matter on which water has no action. To separate the outer skin and the resinous matter the plant must be scalded two or three times with boiling water, whereby the skin cracks, swells, and peels off. After this it is to be put into a boiler with about three quarts of water for every pound of the plant, and about half an ounce of potash or soda (which assists the extraction) and the boiling should be continued till the liquor acquires a considerable degree of gummy consistence. The liquor is then to be taken out and strained from the plant, and fresh water added to the same material, further to exhaust the gum. The several liquors, after standing some hours to settle, and then removing the dregs, are to be boiled down in a regulated heat to the consistence which is required for use, but not further, lest it should burn and become coloured. It requires two or even three boilings entirely to exhaust the lichen of its mucilage.

The method to be pursued in extracting the mucilage from other plants is so similar that nothing more need be added on the subject. The substances the most likely to interfere with the purity of the gum in those succulent plants that abound with mucilage, are for the most either insoluble in water or coagulable at a boiling heat; so that a judicious management of the boiling and clarification will generally succeed with those vegetables where the mucilage is in sufficient quantity to repay the trouble of extraction.

Another species of native mucilage, somewhat differing from any of the preceding, is gum tragacanth. This is a white opake gum, in the form of twisted shreds, seldom free from visible impurities, and of a remarkably tough almost horny consistence, so that it cannot be reduced to fine powder without considerable labour. It exsudes from the stem and branches of a very thorny shrub (*Astragalus Tragacantha.* Linn.) which grows on the island of Candia, and other parts of the Levant.

The juice dries in the sun, and being collected by the shepherds, is sent to Europe without any preparation. It differs from Gum-Arabic in being, properly speaking, hardly soluble in water, but when it is covered with water it swells prodigiously in the course of some hours, and absorbs so much of the fluid as to become soft and pulpy, but will not resolve itself into a liquid by any further addition of water. In this soft pulpy state it will readily mix with other mucilages, and may be spread thin over any surface, and it then dries into a very firm cement. It is employed much in book-binding, mixed with paste, and is found to make a very strong cement.

We proceed to the chemical properties of mucilage in general. When a mucilage (Gum-Arabic for example) is distilled *per se* in vessels arranged so as to detain all the products, there first comes over some pure water, which is immediately followed by a reddish-brown acid liquor, mixed with a little brownish oil and much carbonic acid gas and carburetted hydrogen. This acid liquor is very sour to the taste and has an empyreumatic smell, and has been called the pyro-mucous acid. It is altogether produced by the action of fire, as the mucilage in its natural state gives no indication whatever of acidity. The same acid is produced by the distillation of sugar, farina and many other vegetable matters.

The pyromucous acid is incapable of crystallizing or assuming the solid form. It rises very readily at a boiling heat, and has a strong, pungent, burnt, acid taste. It may be concentrated by freezing in the same manner as common vinegar. It unites with the alkalies and earths, and with several of the metallic oxyds, forming salts which in the properties of easy or difficult solubility, crystallization, &c. resemble very closely the corresponding salts formed with the acetous acid; and from the analogy of the other empyreumatic acids it appears probable that the pyromucous is chiefly acetous acid intimately united by distillation with empyreumatic oil and other products of the mucilage altered by fire.

The action of the nitric acid upon gum-mucilage has excited some attention on account of the many new products formed by the mutual decomposition of these substances, and particularly the formation of a peculiar acid, the Mucous. This acid is found to be the same as that discovered by Scheele to be produced by the action of nitric acid on sugar of milk, which has been partially described under the article *Milk*.

When nitric acid is moderately heated with half its weight of gum-arabic, only till nitrous gas begins to be disengaged, there deposits on cooling a white powder, which when collected and washed is the mucous acid.[c] It has a granular feel and tastes slightly sour. When heated

[c] Fourcroy.

per ſe to decompoſition it gives a red ſharp-taſted oil, much carbonic acid gas, and a portion of it ſublimes in brown ſcales ſmelling like the benzoic acid. The dry mucous acid is very ſparingly ſoluble in water. The hot ſaturated ſolution depoſits on cooling brilliant ſcaly cryſtals. It decompoſes the carbonated alkalies at a boiling heat, expelling the carbonic acid and forming perfectly neutral ſalts.

The acid of ſugar of milk or the ſaccholactic acid (according to Scheele[d]) forms with carbonat of potaſh ſmall cryſtals that require eight times their weight of boiling water for ſolution, but moſt of the ſalt is depoſited on cooling. The ſaccholat of ſoda is much more ſoluble, hence if to a ſaturated ſolution of this ſalt ſome potaſh be added, a copious depoſition of ſmall cryſtals of ſaccholat of potaſh takes place owing to the ſuperior affinity of the acid for potaſh. The ſaccholactic acid forms with all the earths ſalts inſoluble in water, and hence it decompoſes the ſoluble ſalts of the ſame earths, ſuch as the nitrats or muriats, and forms a white ſaline precipitate with them. It alſo decompoſes in the ſame manner the ſolutions of ſilver, mercury, and lead.

When the acid liquor, which remains after the ſaccholactic acid has been depoſited from the ſolution of ſugar of milk in nitric acid, is boiled with a freſh quantity of acid and evaporated, a large quantity of long cryſtals are formed on cooling, which Scheele found to be oxalic acid, and by adding ſufficient nitric acid the whole reſidue may be thus changed. This led to the opinion that the white powder deſcribed as the ſaccholactic acid was only oxalat of lime, but it was found by this excellent chemiſt that ſugar of milk itſelf contained no lime, ſince it gave no precipitate with oxalic acid, and hence this conjecture was erroneous.

Fourcroy has ſome curious and valuable facts on the correſponding decompoſition of gum-mucilage by nitric acid. If the proceſs above deſcribed, viz. of ſimply heating gum with nitric acid till nitrous gas is given out and mucous acid depoſited, be carried no further, the clear liquor from which the mucous acid has ſubſided contains in that ſtate no oxalic acid but only the *malic*, which, as mentioned under that article, is generally the preceding ſtep in oxygenation to the oxalic. Hence it cannot be made to aſſume a cryſtalline form by evaporation, but when concentrated by heat the liquor becomes intenſely ſour and brown or red. It precipitates lime from lime-water, but the precipitate is again ſoluble in an exceſs of the ſame acid, a character which particularly diſtinguiſhes the malic acid from the oxalic, and the latter acid alſo produces its own calcareous ſalt by being added to the acid ſolution of malat of lime.

A further addition of nitric acid aſſiſted by heat completes the converſion of this malic acid into the oxalic.

The mucous acid is not of itſelf alterable by any further treatment with nitric acid, but it is a truly curious phenomenon of complicated chemical affinities that nitric acid and gum, two homogeneous ſubſtances, ſhould by their mutual action at the ſame time produce two acids ſo decidedly different as the mucous and the malic, and not convertible the one into the other by any further action of the ſame acid to which they owed their formation.

If the concentrated ſulphuric acid is poured on gum-arabic, it chars and blackens it, and converts a portion into acetous acid. The muriatic acid alſo produces the acetous, but more ſlowly. The weaker acids ſimply diſſolve gum, but do not alter it.

In the analyſis of vegetable matter the mucilage that exiſts in combination with the other principles may generally be obtained in tolerable purity by the combined action of water, heat, and alcohol. The vegetable, if dry, readily yields its mucilage to the ſimple action of water, then, as mucilage is not coagulated by heat, a boiling temperature will ſeparate the albumen and ſome other principles ſoluble in water, but coagulable by heat. After this the clarified ſolution ſhould be concentrated by ſlow evaporation till it is of a ſlimy conſiſtence, when on the addition of three or four times the bulk of rectified alcohol, the whole of the mucilage will ſeparate in the form of a white powder, and the alcohol boiled on it will take up any reſinous matter which the water had previouſly diſſolved by help of the gum. The alcohol will alſo take up the acetite of potaſh which frequently exiſts in vegetable juices, but will precipitate it along with the mucilage, the phoſphats, and ſulphats, and muriats. The precipitated mucilage is again ſoluble in water, and by ſlow evaporation may be dried to its proper ſemi-tranſparent gummy form, but the above ſalts if ſoluble in water (if perfect accuracy is required) muſt be ſeparated, or their quantity eſtimated by diſtinct proceſſes. As a general obſervation it may be remarked that the conſtituents of organiſed matter, particularly the ſoft ſoluble parts, are ſo intimately blended that it uſually requires a repetition

of the same chemical means used to separate them; so in the present instance it would probably require the solution of mucilage to be twice successively precipitated by alcohol before the separation was compleat.

Several interesting experiments on the intimate nature of mucilage have been made by Mr Cruikshank, which we shall partly notice in this place, and partly refer to the article *Sugar*. Sugar, as Mr. C. observes, has been thought to be a substance of intermediate oxygenation between mucilage and the vegetable acids. Hence it would follow that mucilage and sugar are convertible into each other by a due addition or abstraction of oxygen, supposing that the processes of nature can be at all imitated in the laboratory. That sugar is formed out of mucilage in natural processes appears obvious, for the plants that yield sugar at a certain period of their growth, only contain mucilage at an earlier period. The process of germination also (particularly of barley by malting) decidedly converts mucilage into sugar. By many experiments on the growth of barley in closed vessels and in atmospheres of different gasses, Mr. C. uniformly found that oxygen was necessary to the germination of the seed, and that in the process much carbonic acid was produced. This oxygen may be either absorbed entirely or may immediately combine with the carbon of the seed to produce carbonic acid. Mr. C. then endeavoured to invert the process, and to convert sugar into gum by a *disoxygenating* process. Phosphuret of lime was chosen for this purpose. Some sugar was dissolved in alcohol, and phosphuret of lime added. No gas was disengaged, and the mixture stood in an open phial for some days. The alcohol was then evaporated and water added, which would have disengaged phosphuretted hydrogen had the phosphuret remained unaltered, but this was not the case, as it was now converted into phosphat of lime from the absorption of oxygen (as Mr. C. supposes) from the sugar. The clear liquor being then evaporated there remained a very tenacious substance, bitter to the taste, with scarcely any remaining sweetness; when squeezed between the teeth it had exactly the feel of gum but was more tenacious. It was no longer soluble in alcohol (as sugar is) and when thrown on a red hot iron it burned like gum, and left an insipid bulky charcoal.

The converse of the above experiment was then tried, but it was not found that gum could be converted into sugar by any oxygenating process, the action of the nitric and oxymuriatic acids on gum being to generate acids (as already related) but not saccharine matter.

Some further experiments on the ultimate analysis of mucilage may be extracted from the same author.[e] One ounce of gum-arabic distilled *per se* in a glass retort, gave 3 drams 30 grs. of pyromucous acid mixed with a little heavy oil and a very large quantity of gas. The coal left after a red heat had been continued for some time, weighed 106 grs. which when burnt to ashes in an open crucible left 10 grs. of a white powder, consisting of phosphat of lime and some excess of lime. The pyromucous acid being super-saturated with lime, a strong smell of ammonia was perceived, shewing that azot, one of its constituent parts, must have previously existed in the gum. The gas furnished by the distillation amounted to 273 ounce measures, of which 93 were carbonic acid, and the remainder was hydro-carburet, of the same kind as that produced by burning moistened charcoal.

An ounce of gum-tragacanth treated in the same way, afforded 4 drams 5 grs. of pyromucous acid, and 105 grs. of charcoal, the calcareous ash of which after incineration amounted to 12 grs. and was, as in the former case, lime mixed with phosphat of lime. The ammonia procured from the pyromucous acid was in much greater quantity than from gum-arabic.

An ounce of gum-arabic treated with nitric acid also afforded 3 drams and 36 grs. of oxalic acid, and 6 grs. of a white powder which Mr. C. affirms to be oxalat of lime, and not mucous acid as represented by other chemists, but he does not give the experiments by which this was ascertained.

Gum mucilage is not susceptible alone of the vinous fermentation, for Mr. C. found that when mixed with yeast, and kept for a long time at a warm temperature, nothing like fermentation could be perceived, and the mixture though it acquired a nauseous smell, retained its original taste. It is only when unmixed however that mucilage remains so inactive, for when united with sugar either naturally or artificially, it forms a compound in which fermentation is easily excited.

MUCILAGE, *Animal* or *Animal Mucus*.

Many of the animal fluids contain a substance which resembles vegetable mucilage in being soluble in water, not coagulable by heat, insoluble in alcohol, insipid and giving a slimy consistence to the fluids with which it is mixed, and hence is denominated mucus. The saliva

[e] Cruikshank in Rollo's Essay on Diabetes, or Nich. Phil. Journ. 4to. vol. i. and ii.

is a familiar example of a mucilaginous animal fluid. Animal mucus resembles gelatin so closely both in its ultimate analysis and in many other properties, that the one is considered by Mr. Hatchett as only a modification of the other, and most of what has been described in the article Gelatin will therefore apply here.

Dr. Bostock[a] has however very clearly pointed out a very decided difference between the two in the manner in which they are acted on by the aqua lithargyri acetati, or Goulard's extract, a preparation of lead, made by saturating boiling vinegar with litharge. This liquor when added to any fluid containing animal mucus, gives a copious white precipitate, whereas it is not rendered sensibly turbid by a solution of pure jelly.

The infusion of galls or tan also which instantly precipitates jelly, has no effect or scarcely any on mucus, and these two tests therefore will be sufficient in most instances to detect the presence of one or the other. Neither mucus nor gelatin are altered by the solution of corrosive sublimate, which however precipitates albumen copiously. Hence in a mixture of albumen, gelatin and mucus, these substances may be separated with tolerable accuracy by the successive application of corrosive sublimate, infusion of galls, and acetated litharge.

It is not easy however to find the exact quantity of mucus by the solution of litharge, for the lead which it contains will be equally precipitated by sulphuric, muriatic, and phosphoric salts, all of which are found in many animal fluids. A further application of reagents might indeed separate the sulphat, muriat, and phosphat of lead, from that peculiar combination formed by mucus and oxyd of lead, but the quantities of each are generally too small to allow of much accuracy in this mode of proceeding.

Animal mucus is generally combined with gelatin and albumen, and always with some salts, and on the whole it is one of the least abundant of the animal fluids.

MURIATIC ACID. *Acide Muriatique*, Fr. *Salzaure*, Germ.

If a small retort or a proof bottle with a curved tube be half filled with well dried common salt, and some strong sulphuric acid be poured upon it, a copious effervescence takes place, and the elastic fluid thus extricated appears in the form of a white vapour as soon as it comes in contact with the atmosphere: when by the evolution of this gas all the common air has been driven out of the retort, the subsequent portions of gas may be collected in the usual manner in glass jars filled with mercury and inverted in a bath of the same fluid. The air thus procured is known among chemists by the name of muriatic acid gas; it is transparent, colourless, and possessed of the same mechanical properties as common air and other elastic fluids. Its specific gravity, according to Fontana, is about = 0.00209, but according to Kirwan, is = 0.00231, that of water being = 1000.0, and of atmospheric air = 0.00123. It has a peculiarly suffocating odour; to the taste is extremely sour and corrosive, and affects vegetable colours in the same manner as other acids. It is instantaneously fatal to animal life, and is incapable of supporting combustion; this peculiarity however belongs to it, that if a lighted taper is plunged into a jar full of it, the flame is considerably enlarged and tinged of a greenish yellow colour before it is extinguished.

Muriatic acid gas is not, properly speaking, combustible, though it unites without difficulty with a considerable proportion of oxygen, forming Oxymuriatic Acid. The affinity between water and muriatic acid is very powerful: even when this substance is in a gasseous state it holds a considerable quantity of water, from which it cannot be freed otherwise than by the decomposition of this latter substance. If a little water be introduced into a jar of muriatic acid gas standing over mercury, an immediate absorption takes place and the whole of the acid suddenly loses its gasseous state, heat being at the same time given out. A similar though not so sudden an effect is produced by charcoal, soft wood, sponge and various other porous bodies, probably in consequence of their containing moisture. A piece of ice introduced into muriatic acid gas is melted as rapidly as if it was laid on a hot coal in consequence of the liberation of caloric during the combination of the water and acid. If alum or any other salt containing much water of crystallization be introduced into this acid gas, an absorption takes place and the salt becomes pulverulent in consequence of the transfer of the greatest part of its water to the acid. Iron filings, wax, phosphorus, sulphur and other inflammable bodies when brought into contact with muriatic acid gas absorb more or less of it, and the residue after washing with water is inflammable;[a] the cause of which will be explained presently when we treat of the decomposition of this acid. Neither azot nor any of the simple or compound inflammable

[a] Edin. Med. & Surg. Journal.

[a] Priestley on Air. Vol. ii. p. 280.

gasses have any action on muriatic acid, with ammoniacal gas however it combines instantaneously, the two airs if rightly proportioned to each other entirely disappearing and solid muriat of ammonia being the result.

Although muriatic acid when in the state of gas is the purest form in which it is known, yet the inconvenience of keeping and applying any substance in this state being very great, it is always used except on particular occasions in a liquid form. Liquid muriatic acid, or spirit of salt, is prepared in the following manner. A capacious tubulated retort is filled about one-third of its capacity with decrepitated common salt (muriat of soda), and the juncture of the retort with the receiver is carefully closed with fat lute: to the receiver is adapted a Woulfe's apparatus, the bottles of which are placed in a frame or small cistern for the sake of keeping them cool by means of ice and water. The Woulfe bottles themselves are more than half filled with distilled water, and then concentrated sulphuric acid, in the proportion of about 6 ounces for every pound avoirdupois, is poured upon the salt through the tubulure of the retort, which is immediately after closed with its glass stopper. As soon as the acid and salt come into contact, the retort and receiver are filled with white vapour, and the disengagement of muriatic acid goes on for some time without the application of heat: when the current of gas through the Woulfe bottles begins to slacken, a pot of lighted charcoal should be placed under the retort, gradually increasing the fire till at a very low red heat no more gas is disengaged. What remains in the retort is now dry sulphat of soda, and the water in the Woulfe bottles will be found to be more or less impregnated with muriatic acid according to the quantity of salt originally made use of. The method pursued in the manufacturing laboratories in England is in general the same as that mentioned above, but with a greater simplicity of apparatus, and the vessel that performs the part of the retort is either of earthenware or of iron; this last however is extremely improper, as a portion of iron always rises with the acid and thus communicates to it that yellow straw colour which distinguishes common muriatic acid. In Germany, where sulphuric acid is dearer than it is in this country, the mode of manufacturing this acid is to mingle accurately one part of common salt with four of dried clay, and to subject the mass to strong ignition in iron or earthen vessels; at a high temperature the alkaline base of the salt combines with the earth, and the gaseous acid as it passes over is received into water where it is condensed in the usual way.[b]

If a portion of water be confined in a jar over mercury, and muriatic acid gas be let up into it, a quantity of gas equal in weight to the water will be absorbed, while its bulk will be increased, according to Dr. Priestley, from 1 to 1.5, and according to Kirwan from 1. to 1.33: hence the specific gravity of this liquid acid, according to the former, is = 1.33, and according to the latter = 1.5: but the specific gravity of the strongest muriatic acid that can be made and kept in the common method does not exceed at 60° Fahr. 1.196. Pure liquid muriatic acid is as colourless as water; when exposed to the air it emits a white vapour; it affects the smell and taste in the same manner as the muriatic gas does: it combines with the alkalies and earths, forming neutral salts. Its action upon iron and zinc is very rapid and accompanied by a copious disengagement of hydrogen gas; at a boiling temperature and in open vessels it oxydates and dissolves copper, tin, bismuth, lead, cobalt, manganese, antimony, and arsenic; silver is also affected by it though very slightly; it seems to have no action whatever on gold, platina, mercury, tungsten, molybdena, tellurium and titanium. It dissolves all the metallic oxyds and is an acid of remarkable activity. When heated for some time in closed glass tubes it corrodes them very sensibly, taking up the oxyd of lead from the white glass and the alkali from green glass.[c]

Muriatic acid is capable of decomposing in part the strongest nitric acid, being itself at the same time converted into the oxygenated muriatic acid, as may be seen more at length in the article NITRO-MURIATIC ACID. For the same reason also the alkaline nitrats are decomposable by muriatic acid, as has been ably shown by Cornette.[d]

Various attempts have been made to decompose the muriatic acid, and because in most of the experiments a quantity of hydrogen made its appearance, this substance was supposed by many to be the acidifiable base of the acid. From more recent and accurate examinations however it appears highly probable that the hydrogen in all these cases arises not from the decomposition of the acid but of the water, which it always contains in a greater or less proportion. The most satisfactory experiments relative to the supposed decomposition of muriatic acid are

[b] Gren. Syst. Hand. der Chim. i. p. 467. [c] Priestley.

[d] Mem. de l'Acad. des Sciences for 1778, pp. 44—333.

those of Mr. W. Henry,[e] the principal results of which we shall proceed to detail. When muriatic acid gas confined in a glass jar over mercury is subjected repeatedly to the electric shock, it undergoes a diminution of bulk, a white matter appears on the inside of the tube, and upon subsequent mixture with water a portion of gas remains unabsorbed, and appears to be hydrogen in a state of considerable purity. The diminution of the acid gas and all the other accompanying phenomena are the most remarkable when the acid operated upon is that which is first disengaged on mixture of sulphuric acid and common salt: the part that comes over during the latter end of the process is considerably less affected by the electric shock than that which is first produced; and if the gas has been previously dried for some days by contact with solid muriat of lime, the diminution of bulk by electrization is scarcely perceptible. The white matter that appears during the process is mild muriat of mercury or calomel: hence it is obvious that in these experiments oxygen and hydrogen are disengaged, of which the oxygen together with part of the muriatic acid unites with a portion of the mercury, while the hydrogen and the residue of the acid remain in the state of gas. Now as the component parts of water are oxygen and hydrogen, and as the amount of these substances disengaged by the electric shock is in an inverse proportion to the dryness of the gas, it is reasonable to conclude that the hydrogen and oxygen proceed from the decomposition of water and not of muriatic acid. This conclusion is further strengthened by another fact, namely, that after a number of shocks have passed through the gas its diminution ceases, and if it is then transferred to a fresh tube over mercury and again subjected to the action of electricity, no further change in bulk is experienced, nor is there any formation of calomel; but if the acid were really decomposed, the production of calomel ought to continue as long as any acid gas remained. Again, when muriatic acid gas is electrified in a glass tube without the contact of mercury, the result is found to be oxymuriatic acid gas mixed with hydrogen. Several attempts were made by Mr. H. to deoxygenate muriatic acid gas by mixing it with carburetted hydrogen and electrifying it, but without success: the mixed gasses were indeed expanded and carbonic acid was produced, but these changes were obviously caused merely by the decomposition of the water, since after they had entirely ceased a little water was introduced, and the quantity of muriatic acid absorbed was equal to what would have been taken up if the acid gas had been electrified by itself.

So various and uniformly ineffectual have been the attempts to decompose this acid, that we must conclude either that it is a simple body, or if, like many other of the acids, it be considered as a compound of a combustible base with oxygen, the affinity between the two must be regarded as more powerful than that of any of the known combustible bodies with oxygen.

The affinities of muriatic acid are arranged in the most recent tables in the following order. Barytes, potash, soda, strontian, lime, ammonia, magnesia, glycine, alumine, zircon, metallic oxyds. This order however is not correct, for the oxyds of silver, mercury, lead, and probably antimony, are capable of decomposing most if not all the neutral and earthy muriats.

The use of muriatic acid in the laboratory is very considerable, but in medicine and the arts it is but little employed except in the form of muriat or combined with some salifiable base. It is worth remembering by the chemist that nothing takes off the crust of oxyd of iron, which in many experiments is found adhering with remarkable closeness to glass vessels, so safely and quickly as a little warm dilute muriatic acid.

Muriat of Potash, or *Salt of Sylvius*.

Muriat of potash is rarely if ever found native except in the ashes of a few plants and in some animal fluids, especially milk. To obtain it pure it must be formed either by the direct union of muriatic acid and potash, or its carbonat, or by decomposing common salt by potash. The former is the best method for a chemical investigation of its properties.

If a saturated solution of this salt is slowly evaporated the muriat of potash separates in the form of regular cubes, which have a salt and bitter taste, together with a degree of pungency like muriat of ammonia. It dissolves in three times its weight of cold water, and by boiling somewhat more is taken up, and hence a clear hot saturated solution deposits a portion of salt by cooling, in which respect it differs from pure muriat of soda. Muriat of potash when briskly heated sharply decrepitates, but does not liquefy in its water of crystallization, this being only about 8 per cent. which flies off at a heat below ignition. At a full red heat the salt melts, and if the heat is further urged the salt itself flies off in a

[e] Phil. Transf. for 1800, p. 188.

white denſe vapour, which however is not decompoſed.

This ſalt is ſomewhat deliqueſcent in a moiſt air. If a little ſulphuric acid is poured on it the muriatic acid is expelled in the form of white fumes. The nitric acid decompoſes it partially and cauſes the evolution of nitro-muriatic acid. The phoſphoric acid alſo expells the muriatic at a high heat.

This ſalt is compoſed according to Kirwan, of 64 of potaſh and 36 of acid when dried at 80° of which however about 8 are mere water of cryſtallization; and 100 parts of the ſalt when decompoſed by nitrat of ſilver give 217.65 of dry luna cornea.

Muriat of potaſh is not uſed. It is rarely produced in the large way in chemical proceſſes except when the comparative prices of potaſh and ſoda make it worth while to procure ſoda from ſea ſalt by means of potaſh, as will be mentioned in the next article.

Muriatic acid may be procured from muriat of potaſh in the ſame way as from muriat of ſoda, but the bitter taſte and rather greater deliquſcence of the former, render it probably ſcarcely fit for any of the culinary uſes of common ſalt.

Muriat of Soda. Sea Salt. *Common Salt.*

This ſalt exiſts abundantly native either as a ſolid foſſil or diſſolved in water. In the former caſe it ranks as a peculiar mineral ſpecies, and will be deſcribed accordingly.

Rock Salt, or Fossil Salt, or Sal Gem.—*Steinſalz.* Wern. *Sel gemme.* Broch.

Of this ſpecies there are the two following varieties.

Var. 1. Foliated Rock Salt.

Its colour is uſually greyiſh, yellowiſh, or milk-white, or aſh-grey, ſmoke and pearl-grey. It alſo though rarely occurs fleſh, blood or brick red, and ſtill more rarely violet or ſky-blue or green. It is found in maſs, diſſeminated, in large columnar or ſpherical diſtinct concretions, or cryſtallized in cubes. The recent fracture is brightly ſhining with a luſtre between vitreous and reſinous. Its fracture is ſtrait foliated in three rectangular directions; hence the form of its fragments is cubical, but this is the caſe only when it is cryſtallized, the maſſive varieties are thick foliated approaching to ſlaty, and break into blunt-edged irregularly wedge-ſhaped fragments. It is ſemi-tranſparent, paſſing on one hand into tranſlucent and on the other into tranſparent. It is moderately hard and not very brittle. To the touch it is ſmooth and almoſt greaſy. Sp. gr. 2.14. It is ſalt to the taſte, it is deliqueſcent in a moiſt atmoſphere, is readily ſoluble in water, decrepitates ſtrongly when laid on hot coals, and is fuſible at a low red heat.

Var. 2. Fibrous rock ſalt.

Its colour is greyiſh-white, yellowiſh or pearl-grey, lavender or violet-blue, or fleſh-red. Its internal luſtre is pearly varying from ſhining to gliſtening. Its fracture is fibrous, either parallel, with fine and curved fibres, or divergent, with coarſe and ſtrait ones. Its fragments are wedge-ſhaped or ſplintery. It varies from tranſlucent to ſemi-tranſparent: it is tender and brittle: in other reſpects it agrees with the preceding variety.

Rock ſalt forms a peculiar ſpecies of rock, the proper geological ſituation of which is between the oldeſt ſecondary gypſum and ſecondary ſandſtone: it forms continuous beds of great thickneſs, and often occurs in large ſolitary blocks: it is always accompanied by ſemi-indurated clay, for the moſt part ſtrongly impregnated with ſalt; and alternates with beds of ſwineſtone, gypſum, limeſtone, and ſandſtone. The beds of ſalt are moſtly below the ſurface of the ground, but ſometimes it riſes into hills of conſiderable elevation. At Cordova in Spain, according to Bowles, there is a hill between four and five hundred feet high, compoſed entirely of this mineral.

Rock ſalt, though not of very frequent occurrence, is however by no means rare; the moſt celebrated mines are thoſe of Wielicza in Galiicia, of Halle in the Tirol, of Poland, of Caſtille in Spain, and Cheſhire in England. In the province of Lahor in Hindoſtan, is a hill of rock ſalt of equal magnitude with that near Cordova. The mines of Iletſki in Ruſſia, yield vaſt quantities of this ſubſtance; it is ſo plentiful in the deſart of Caramania, and the air is ſo dry, that it is there uſed as a material for building: it forms the ſurface of a large part of the Northern deſart of Lybia, according to Horneman; it is alſo found in abundance in the deſarts of Peru.

Muriat of ſoda has a pure ſaline taſte without any mixture of bitterneſs. It cryſtallizes in cubes when obtained by ſlow evaporation from its ſolution, but when procured by a boiling heat (as is the caſe with moſt of the ſalt uſed for culinary purpoſes) the form is that of a hollow inverted pyramid, reſembling a hopper, and is made by a ſucceſſive aggregation of cubes round a central one, whilſt floating on the ſurface of the brine,

whilst the increasing bulk of the mass causes it gradually to sink lower in the liquor.

Common salt is very soluble in water, 8 parts of the latter will dissolve somewhat less than 3 of salt at a moderate temperature, and scarcely any more is taken up at a boiling heat, so that no salt can be obtained from a hot saturated solution by mere cooling, but only by evaporation of the fluid. Salt contains but little water of crystallization, and hence when thrown in the fire or suddenly heated it decrepitates or flies to pieces with a crackling noise. If heated red hot it melts, and at a still higher temperature it flies off in the form of dense white fumes, but is not decomposed by volatilization.

It is composed according to Kirwan, of 53 per cent. of soda, and 47 muriatic acid and water, and the quantity of real acid is such that 100 parts of the crystallized salt decomposed by nitrat of silver, will give 233½ of luna cornea,[a] of which the mere acid is 38.6.[b] It must be observed that there is some difference in the analyses of different chemists, but taking the above data as correct, 100 parts of crystallized muriat of soda will contain 53 of soda, 38.6 of acid, and 8.4 of water.

Common salt is generally said to be insoluble in alcohol, however Mr. Kirwan found that in a moderate temperature 100 grs. of alcohol, at .900 sp. gr. dissolved 5.8 grs. of salt; the same quantity at .872 sp. gr. dissolves 3.6 grs; and even at .834 sp. gr. it dissolved ½ a grain.

Muriat of soda may be decomposed in a variety of ways: its acid is readily and totally expelled by the sulphuric at a moderate heat: its alkali may be procured by a variety of methods, many of which are used in the great way, and will be shortly described at the end of this article.

We now proceed to the mention of methods by which are procured the immense quantities of common salt employed by man in almost every country on the face of the globe.

It has been already mentioned that native salt is found, either solid, under the surface of the earth (when it is often termed sal gem, and of which that in the county of Chester in this country is a striking example) or dissolved in natural brine springs, which are always found in the neighbourhood of rock salt: or it is left by the spontaneous evaporation of many inland lakes and pools in different parts of the world: or lastly, an inexhaustible store of it is contained in the waters of the ocean. Sometimes the rock salt is found sufficiently pure to be used without any preparation; this however is rare, for by far the greater part of the salt used throughout the globe, is got by evaporation of salt water, either by natural or artificial heat, or often by both. The general process of making salt from brine by artificial heat, is very simple and obvious, being little else than putting the brine into a broad shallow iron pan, bringing it to a boiling heat by furnaces underneath, and continuing the evaporation nearly to dryness, during which the salt gradually separates as the water is dissipated, and is afterwards collected and gently dried. But there are several circumstances relating to salt-making which deserve the attention of the chemist, and require to be related more at large.

We shall give in a few words the process of salt-making as practised in Cheshire, being the place whence most of the salt used in this country is obtained.[c]

The brine is first pumped up from very deep wells, by powerful machinery, and is discharged in a large pond or reservoir. If the brine is weak in salt, it is generally strengthened and nearly saturated by throwing in a quantity of the more impure rock salt dug up in the neighbourhood, particularly in those salt-works that have the convenience of water-carriage from the pits. There is a considerable difference in the purity of the brine from different pits, all contain a small portion of earthy salt, chiefly sulphat of lime, and a small quantity of carbonat of lime held in solution by an excess of carbonic acid, and frequently also a little carbonat of iron. The purest brine is perfectly limpid, of a pure saline taste, and a peculiar cold green hue. This last indicates the absence of iron, for when even the smallest admixture of oxyd of iron is present, the water has a yellowish cast, and the salt made from it never acquires that delicate blue-whiteness which is considered as a criterion of its perfection. The salt-pans where the brine is boiled down are oblong shallow troughs of wrought iron, usually from 20 to 30 feet long and broad, and about 9 to 12 inches deep. They are set strongly upon masonry, over a large furnace, the flues of which draw all round the pan. The fuel is coal, of which there are many pits at no great distance. Each pan stands in a small covered building, with a pyramidal roof formed of boards sloping downwards, but with a considerable interval between each, so as to keep off the rain, and at the same time to allow of a free passage for the steam of the boiling brine.

[a] Klaproth. [b] Kirwan, Min. Waters. p. 239. [c] Original Communication.

The whole process of boiling, purifying, and evaporating the brine, is performed in this single pan.

The brine after standing some days in the reservoir, is pumped into the pan. When heated to about 100° it begins to grow turbid, owing to the deposition of the carbonat of lime and of iron (if any) by the expulsion of the carbonic acid which held them in solution. This forms a scum on the surface of the brine which is partly removed by a skimming dish, but much of it falls to the bottom, and if suffered to remain would materially injure the quality of the salt. To clear it out the brine is evaporated till it begins to *salt*, that is, till a portion of the muriat of soda begins to separate, and this falling to the bottom mixes with the carbonat of lime and gives it a body, which enables the workman to draw it out. This is carefully done, and the sediment thus obtained (called *clearings*) is thrown away, which from a pan of 24 feet by 27, usually amounts to about three or four bushels. The evaporation is then continued at a boiling heat, and the salt gradually collects at the surface and falls to the bottom in beautiful crystals of a pure and delicate white, where the brine is good. As the process advances and the salt collects in quantity, it is fished out from the bottom of the pans by wooden vessels, and poured into large hollow wooden cones, with a hole at bottom, and suspended round the side of the pans. Here it drains, and the drainings drop again into the pans. When the process is compleated and the contents of the pan evaporated almost to dryness (which usually takes a single day and a night) the cones full of the salt are taken to a large room made very hot by stoves, where they remain till thoroughly dry.

The grain of the salt is determined by the rapidity of the evaporation and the degree of heat used. In the common salt-making the water is evaporated at a full boiling heat, that is, as fast as possible, and hence the grain is small, and the salt comparatively soft. The contents of a single pan are usually worked off in twenty-four hours, except from Saturday to Monday, when two days are taken, and hence a larger and harder grained salt is made, which is much esteemed in the country for salting cheese.

It is found by experience that some brines will not readily *salt* by mere evaporation, but that some addition is required to make them work well and the salt fall regularly. This addition is generally calve's feet jelly, sometimes glue, sometimes white of eggs, sometimes blood, and in short any animal or vegetable mucilage seems to answer the purpose. It is usual to have standing in a corner of the pan an earthen vessel containing eight or ten pair of calve's feet, to which hot brine is added to extract the jelly, and after the *clearings* are removed and the brine begins to salt, the workman adds a little of the jelly at discretion. The precise use of this addition is by no means obvious, nor is it absolutely necessary, but long experience has shewn it to be useful in many kinds of brine.

Another difficulty sometimes arises. In general the brine when it once has begun to *salt*, goes on to work well to the last, every part of the surface being sufficiently covered with small crystals of salt, which soon grow into a group forming a small floating island of salt, which soon sinks to the bottom by its own weight, and leaves a clear surface above, which again is covered in the same manner. But sometimes from some unknown cause, a thick shapeless crust of salt forms rapidly over the whole pan, which soon hardens to a dry floating cake of salt, preventing in a great measure the escape of the steam, and materially retarding the process. To remedy this a small lump of butter, not more than about half an ounce, is thrown into the pan, which quickly melts and diffuses itself over the dry cake of salt, and causes it to break up and sink, after which the salting goes on well.

After the brine has been evaporated nearly to dryness, and indeed during the latter part of the boiling there is deposited on the bottom and sides of the pan a hard white saline and earthy crust, which strongly adheres to the pan, and is partly fused to its surface by the intensity of the fire in proportion as the sides become dry by the loss of liquid.

This crust daily accumulates and produces much inconvenience, partly by injuring the quality of the salt, but chiefly by increasing the distance between the fire and the brine, and forming a thick coating through which the heat penetrates with difficulty. Hence it becomes necessary about once a month to discontinue the boiling for a day, and to pick and beat off this crust with hammer and chissel often to the great injury of the pan itself. The *pickings* or *pan-scratch* as they are also called are thrown away. Their analysis will be mentioned afterwards.

A very large-grained and beautiful salt is made at Liverpool and some other places by very slow evaporation of saturated brine, and strings or sticks are put into the pan on which the crystals form, as in the making of sugar-

candy. This salt is used in the curing of fish, and is called fishery-salt.

Much of the finest part of the rock salt dug out from the pits near Northwich in Cheshire (the only rock-pits in the kingdom) is exported to Ireland, the West Indies and other parts, and of late years a plan has been adopted of bruising it by rollers and bringing the fragments to the size of the common bay and fishery salt, in which state it is found to answer well for curing fish and meat.

The chemical analysis of the different brines and products or impurities in salt-making will be presently mentioned.

The above method of salt-making has been practised in the Cheshire works with scarcely any variation ever since their first establishment, the methods employed in other countries of concentrating weak brine before boiling being unnecessary here, as there is abundance of strong brine and a further opportunity of saturating the weak by the rock salt.

As the greatest inconvenience in salt-making is the precipitation of the earthy impurities and the difficulty of preventing them from mixing with the salt; a plan has lately been adopted (under patent) in some works near Northwich, of heating the brine in a separate pan to the degree at which the earthy carbonats precipitate, before it is sent into the large salting pan. It is found that the same fire, by extending the flues, will heat this preparing pan which is contiguous to the other, and the time in which one pan-full is worked off is sufficient to bring the fresh portion to the requisite heat, and to purify it considerably.

We shall now relate some of the leading circumstances of the preparation of salt in foreign countries as far as they differ from that above described.

When a weak brine is exposed to the atmosphere the watery part gradually evaporates, and with it the carbonic acid which it contains, the effect of which is to concentrate the solution and also to cause the deposition of the earth and oxyd of iron which the carbonic acid held dissolved. As evaporation much depends on the surface exposed to the air, a very ingenious method has been adopted of promoting this by causing the weak brine to fall successively through large bundles of faggots, whereby a vast consumption of time and fuel in the subsequent evaporation is prevented. This operation is called *graduation*, and the place in which it is performed a *graduating house*.

This consists of a very long range of rows of faggots placed perpendicularly, and rising to the height of about 25 feet and disposed in cones, the summits of which are about 6 feet in diameter, and the bases about 10. Just above the faggots is a trough perforated with holes at small intervals, furnished with stop-cocks, and the whole is covered with a pent-house roof. At the bottom of the faggots is another trough to catch the brine. The length of these houses is determined by the quantity of brine wanted, sometimes it is enormous. In some parts of Germany there are graduating houses six thousand feet long, but in general they are from 200 to 1000.

The weak brine is first raised by pumps to the upper trough, when the stop-cocks are turned and the water made to fall like a shower of rain through the faggots into the trough below. It is then again forced up and undergoes the same operation successively till it is sufficiently concentrated. The state of the atmosphere has the greatest influence on the graduation of the brine. The evaporation goes on the quickest in a dry air with a moderate wind: when the wind is violent much of the brine is carried away in the state of spray or vapour, particularly when the column of faggots is not pyramidal but has the same dimensions throughout. As a proof of this waste Haller observes that in the neighbourhood of these graduating houses the ground becomes in a few years covered with the salicornia and other plants which are known to require a salt soil and flourish on the sea-shore.

It has been mentioned that in proportion as the brine becomes concentrated it parts with its carbonic acid, and deposits carbonat of lime, and hence the faggots of the graduating houses become gradually encrusted, over every twig, with a brown hard earthy matter, consisting chiefly of carbonat of lime. Thus in a course of years the faggots are entirely covered with stalactite as in the common petrefactions, and the surfaces for evaporation become thereby so much diminished that it is necessary to replace them with fresh faggots. The time that one set of faggots will last, is about eight or ten years.

The effect of graduation in concentrating brine is very striking. Baron Haller in his valuable memoir on the subject gives the result of many observations on this and other particulars relating to the salt-works in Switzerland of which he was the director.[d]

[d] Mem. de l'Acad. for 1764.

The brine ſprings in this country ſeldom contain more than one per cent. of ſalt in the natural ſtate, but by mere graduation the brine is brought as high as 20 per cent. after which it is ready to be boiled down as uſual. To effect this concentration therefore, 20 parts of brine muſt part with 19 by evaporation through the faggots. The depoſition of ſtalactite hardly begins till the brine is brought to 5 per cent. of ſalt, and it ceaſes altogether when it is brought to 15 per cent. The graduation of the brine becomes ſlower as the concentration increaſes. With regard to the actual effect of a given quantity of faggots, Haller finds that at a mean degree of concentration or 10 per cent. the evaporation of a ſingle day in Switzerland, taking the average of the entire year, is 1100 cubic feet, (reckoning the weight of the cubic foot at 46 lb. of 18 oz.) in a row of faggots 20 feet high, and 735 long. When the ſun ſhines ſtrongly, the exhalation is more than double the above quantity.

A graduating houſe of the above dimenſions is eſtimated to have always at work about 1,912,000 lbs. of brine, and this quantity is furniſhed eleven times in the year to the boiling pans. There appear to be two inconveniences in graduation, one, which is but trifling is, that the brine extracts at firſt ſome colouring matter from the faggots, which is never totally got rid of in the ſubſequent evaporation, ſo that the ſalt has a little browniſh tinge. The other is more ſerious, and it is the actual loſs of brine by graduation either when the wind is too violent, or the proceſs managed unſkilfully and the faggots not well arranged. This in ſome ſalt works is eſtimated as high as from 30 to 40 per cent.

Klaproth has ſome valuable experiments on graduated brines in his analyſis of the ſalt ſprings of Königſborn, which is a ſalt mountain extending from Paderborn to the Dutchy of Cleves, and into the biſhoprick of Munſter. The brine is found much ſtronger the deeper it is drawn. That obtained at 50 feet from the ſurface contains only 1¼ to 2 per cent of ſalt, at 80 feet it is 2¼; and at 120 feet it riſes to 3¼ or 3½ per cent.

The method purſued by this excellent chemiſt in the analyſis of the brine, may be alſo ſhortly mentioned as a direction to the reader who may wiſh to repeat the experiments.

1. Fifty cubic inches of brine (each equal to 290 grs. of diſtilled water) were evaporated to dryneſs in a ſand heat, and the weight noted.

2. The reſidue was covered with alcohol and digeſted in a moderate heat for 24 hours.

3. The alcoholic ſolution was poured off and evaporated to dryneſs, and freſh alcohol poured on the reſidue in order to rediſſolve all the ſalts except the ſmall portion of common ſalt which the firſt alcohol had taken up. The laſt alcoholic ſolution was then evaporated to dryneſs and the reſidue weighed.

4. The dry reſidue from the laſt alcoholic ſolution conſiſted of muriat of lime and muriat of magneſia, and the weight of each was determined in the following manner: the reſidue was diſſolved in water, and the earth precipitated by carbonat of ſoda. This earth, well waſhed, was then combined with ſulphuric acid to exceſs, and after the mixture had ſtood a while in a warm place, the exceſs of acid was abſorbed by adding carbonat of lime. The ſolution was then evaporated conſiderably (removing the ſulphat of lime as it was formed) and then expoſed to exhalation in the open air, whereby the ſulphat of magneſia was ſeparated in cryſtals. Theſe laſt were collected, rediſſolved in water, decompoſed by ſoda, and the magneſia ſaturated with muriatic acid and evaporated to dryneſs. It was then pure muriat of magneſia brought to the ſtate in which it exiſted in the dry reſidue of the brine, and the weight of the muriated lime originally mixed with it was found by ſubtracting the weight of the muriat of the magneſia from that of the entire alcoholic reſidue.

5. The dry ſalt remaining after the ſeparation of theſe earthy muriats was then diſſolved in water and filtered.

6. What was left on the filter conſiſted of ſulphat and carbonat of lime, and oxyd of iron. When weighed, it was treated with muriatic acid, and the ſulphat of lime left on the filter. Ammonia was added to ſeparate the iron which was collected and weighed.

7. The clear ſolution of *No.* 5 might ſtill contain ſulphat of lime; it was therefore boiled with carbonated ſoda, when a carbonated lime fell down. The ſoda added was then neutralized by muriatic acid, and muriat of barytes added, which gave a precipitate of ſulphat of barytes, ſhewing therefore the exiſtence of ſulphuric acid in the brine, which muſt have been combined with the lime obtained by the ſoda. The quantity of ſulphat of lime was inferred from the united weights of the car-

bonat of lime and the sulphat of barytes, and from the quantity of the latter also it was proved that no other sulphat existed than that of lime. The same was also shewn by the gradual solution of the salt in a mixture of two parts of alcohol and one of water, for the sulphats will not sensibly dissolve in this mixture without heat.

To shew the precise effect of graduation we shall now give Klaproth's analysis of brine first in its natural state, and then through the successive stages of concentration in the graduating house.

The natural brine was as follows: the specific gravity 1.024:

The entire residue from 50 cubic inches weighed 521 grs. which was composed as follows:

Muriat of lime - - - - -	30 grains
—— Magnesia - - - -	½
Carbonated lime - - - -	11
Carbonated oxyd of iron -	½
Sulphat of lime - - - -	15
Muriat of Soda - - - - -	464
	521

This brine was brought by the first graduation to the specific gravity of 1.060. The residue from 50 cubic inches now weighed 1285 grains, and consisted of

Muriat of lime - - - - - - -	65 grs.
—— Magnesia - - - - -	1½
Carbonated lime with a little iron	4½
Sulphat of lime - - - - - -	44
Muriat of Soda - - - - - -	1170
	1285

The second graduation brought the specific gravity to 1.076, and the residue to 1615 grs. which was composed of

Muriat of lime - - -	75 grains
—— Magnesia - -	2
Carbonat of lime - -	3
Sulphat of lime - -	48
Muriat of soda - - -	1487
	1615

The third graduation gave a specific gravity of 1.086 and a residue of 1850 grains composed of

Muriat of lime - - - -	82 grains
—— Magnesia - - -	3
Carbonate of lime - -	3
Sulphat of lime - - -	52
Muriat of soda - -	1710
	1850

By comparing the above analyses we may infer what must be the effect in graduation both in concentrating the brine and in freeing it from a part of its impurities, and what must be the composition of the stalactitical incrustation on the faggots of the graduating house. It would have been more accurate if the successive changes produced in an individual brine had been noted, but in the salt-works here mentioned there appear to be a number of springs all slightly differing from each other in the proportion of ingredients, the brine of which is mingled together before graduation. On the whole however it is obvious that the great loss of the ingredients of the brine is in the carbonat of lime, for since the entire residue of a given quantity of the rough brine amounts to only 521 grains, and the residue of brine thrice graduated is 1850 grains, the proportion of each ingredient (were there no loss) should be respectively upwards of 3½ times as much in the graduated as in the rough brine. Thus the quantity of carbonat of lime should in the graduated brine be about 39 grains, whereas it is actually only 3. This loss of carbonat of lime therefore should be found in the incrustation of the graduating faggots, and accordingly this is the case; for by analysis 960 grains of this crust contains no less than 828 of carbonat of lime. The exact analysis of this substance is as follows:

Impure common salt - -	4 grains
Sulphat of lime - - -	25
Carbonated oxyd of iron -	92
Carbonated lime - - -	828
Moisture - - - - - -	11
	960

The carbonated oxyd of iron also disappears from the brine during graduation, and is found in the incrustation.

When the brine is boiled down, what remains of the carbonat of lime in it is precipitated along with selenite and common salt, and forms that hard crust which adheres so firmly to the pan, and has been described already under the term *pickings* or *pan-scratch*.

One pound of this analyzed by Klaproth is composed as follows:

	oz.	dr.	gr.
Moisture - - - - - -	1	6	0
Muriated lime - - -	—	1	10
——— Magnesia - - -	—	—	10
——— Soda - - - - -	4	4	40
Carbonat of lime - - - -	1	2	30
Sand - - - - - - - -	—	3	30
Sulphat of lime - - - -	7	6	0
	16	0	0

The *mother water*, or liquor left in the salt pan after all the salt that it is thought proper to work off is taken out, is a very dense bitter fluid. Its specific gravity is as high as 1.218. Fifty cubic inches yielded by evaporation 5440 grains of dry salt, composed of

Muriated lime - - - - - -	660
————Magnesia - - - -	840
Sulphat of lime - - - - -	100
Common salt - - - - - - -	3840
	5440

It is remarkable that the muriated magnesia is here a fourth more than the muriated lime, whereas in the brine, both rough and graduated, it is not more than $\frac{1}{30}$ or $\frac{1}{40}$ of the muriated lime. Hence much of the latter must be decomposed during the boiling, to which Klaproth attributes the strong smell of muriatic acid perceivable when the evaporation is nearly compleated.

A very full and accurate account of all the processes employed in the large salt-works of Salins, Moyenvic, and other brine springs in Franche Comté in the South of France on the borders of Savoy, is given by Nicolas, who examined them on the spot.[e]

We shall not transcribe it at large to avoid repetition, the general method being that already mentioned, viz. of concentrating the brine by graduation, then boiling down in iron pans. But some varieties of practice and other circumstances contained in this valuable memoir are worth relating.

The brine gives by analysis the following ingredients. One French pound (of 16 oz. and 576 grs. to the ounce) contains of

	oz.	grs.
Muriat of soda - -	7 —	529
Sulphat of lime - -		23
Sulphat of soda - -		75
Muriat of lime and magnesia		81

Three kinds of salt are made at Salins, namely, large grained, small-grained, and loaf-salt. The common or small grained is that which is made at a boiling heat, continued to the last. The large-grained is made in small pans placed contiguous to the boiling pans and supplied by the same fire, the flues being continued under them. The heat in these is but slow and the evaporation moderate, which allows the salt to form in larger crystals. The earthy-saline scum which forms during the boiling, is afterwards lixiviated to extract the salt which it contains. The *schlot* or *pickings* from the pans contains much Glauber's salt which is also extracted by hot water, and when the solution is so far concentrated that it would crystallize by cooling, it is stirred constantly till cold, which makes the salt assume a needled form like the common Epsom salt, and is sold as such.

A very ingenious plan has been introduced here of applying the principle of evaporation by the atmosphere, not only to the concentration of the brine but to the actual crystallization of the salt which it contains. For this purpose the brine after common graduation on faggots, is heated in the pan till it begins to salt. It is then conveyed to another graduating house about 250 feet long, divided by party walls into six arches. These support troughs extending the whole length of the building and furnished with proper holes for the brine to fall down. The space under each arch is filled with forty rows of endless cords stretched vertically on wooden frames, each of which contains 25 double cords parallel to each other, and about three inches asunder. The whole building contains 6000 of these double cords about 3 or 4 lines in diameter, and about 30 feet long. The flooring of the building is made of fir planks well put together, and gently sloping to one end to convey the brine as it falls, into a large reservoir from which it is again pumped up to the upper trough. The side of the building most exposed to the weather is protected by a canvas. The hot brine as it passes from the boiler is sent into the upper trough and then falls down every one of the cords in a copious stream, round which the salt gradually crystallizes in a stalactitical form. When the crust of salt forms a cylinder from 2 to 2½ inches in diameter it is taken off, and the process repeated. Each operation produces from 3500 to 4000 quintals of excellent salt, and requires about a month to be formed; and as this work can only

[e] Ann. de Chem. tom. xl.

be carried on in the height of summer, the cords can be charged no more than twice or at the utmost thrice in the year.

The salt is broken by a kind of moveable flail set in a frame in which each row of cords is placed in turn.

The country of Saltzbourg on the borders of the Tyrol furnishes a vast supply of salt, which is procured from a large salt mountain near the town of Hallein. No brine springs are found here, which is a remarkable circumstance, as in general the neighbourhood of rock salt abounds in water. The rock salt however is not worked out in mass in this country, but an artificial brine is made in the following manner.[f] A horizontal gallery is cut in the mountain through the middle of the rock salt, from 50 to 200 fathoms in length, 5 feet high, and 4 wide. This gallery is supported above and on the sides by planking, and the opening is shut up by an earthen wall. Fresh water is then let in from springs collected on the upper part of the mountain, till the whole gallery is filled. In two or three weeks the water by resting on the salt has acquired 22 per cent. of saltness, after which it is drawn off and boiled down as usual. This process is then repeated as often as necessary, till by degrees the galleries by the gradual solution of the sides and floor enlarge into vast caverns. The roof never enlarges, which is rather a singular circumstance.

The sea is an inexhaustible source of salt, and vast quantities of it are made from sea-water in different countries. Sea-water is but a weak brine, the solid contents of which vary in different parts of the world. In the Baltic it is not more than $\frac{1}{40}$, in the British Channel about $\frac{1}{30}$, and taken at a great depth near the Equator, it is about $\frac{1}{23}$, in which state its specific gravity is 1.0289, according to Bergman, who has analysed it. By the experiments of this excellent chemist it appears that an English wine pint of this sea-water (of 28.875 cubic inches) contained

	grains.
Of Muriated soda -	241
— Muriated magnesia	65.5
— Sulphat of lime -	8.
	314.5

A small portion of carbonated magnesia also separates during the evaporation.

Sea-water therefore contains a very large proportion of other saline matters besides common salt, more so than the common brine springs, and this being chiefly muriated magnesia, the salt procured from sea-water is apt to be bitter and subject to deliquescence unless a good deal of pains be taken in the boiling, or unless the evaporation be conducted very slowly. There are several ways of getting the salt by sea-water: in warm climates this is done altogether by the heat of the atmosphere, and this forms the large-grained strong dry salt called *bay salt*, which is preferred to any other for curing provisions that are intended to keep for a length of time. Bay salt is made in great perfection in Spain and Portugal, by the Biscayans, and on the Mediterranean shores of France, and in the Bahama islands in the West Indies. The process is simple and requires but little apparatus of any kind. The first requisite is a sea marsh, or shallow artificial pond, near enough to the sea to be filled at high water. A level shore must therefore be chosen, and the soil must be clayey to retain the water. The bottom of the pond is then laid out perfectly even, and beaten hard and smooth, and a channel with flood-gates is cut to the sea. The salt pools consist always of a large reservoir communicating directly with the sea at one end, and at the other with a number of smaller pits or beds on which the salt is made. The water is first evaporated by the sun's heat considerably in the reservoir, and then conveyed to the salt-beds, which are only a few inches deep, and in which the evaporation is compleated also by the sun and wind, and the salt separates first in the form of a white crust which is broken from time to time to expose a fresh surface to the air. The concentrated brine yields salt about twice and sometimes thrice a week in summer. The first saline crust that forms is small-grained, the latter large. Bay salt has generally a little tinge of colour, green or brown, according to the soil on which it is formed. It is only made in the summer months.

Another way of making salt from sea-water, and which is practised much on the French and other coasts of temperate climates, is partly by the atmospherical evaporation and partly by boiling, for the summers are not hot enough in this climate to make salt by mere exposure of brine to the air. The general mode of proceeding is that already mentioned, that is to say, the sea-water is exposed during the summer in shallow artificial pools, where it becomes highly concentrated, and this is afterwards boiled down in iron pans in the usual mode. This way is adopted largely in Scotland, and in a few parts of England, particularly at Lymington. The

[f] Journal des Mines, No. 76.

mother water that remains after moſt of the ſalt has been extracted, contains much muriat of magneſia, and this is advantageouſly converted into the *ſulphat of magneſia*, as will be mentioned under that article.

There is ſtill another method of extracting the ſalt from ſea-water, which is by collecting the ſand that has been repeatedly moiſtened by the ſea-water and dried, and lixiviating it in reſervoirs, where it forms a very ſtrong brine, which is then boiled down as uſual. This way is much practiſed on the weſtern coaſt of France, particularly in Lower Normandy, and at the iſles of Oleron and Rhé.[g]

The ſpot being choſen (which ſhould be on a level ſhore with a clean ſand) the neceſſary buildings are erected namely, evaporating pans, ſtore-houſes, covered ſheds, &c. and an area of three or four acres is ſelected a little below the level of the ſpring tides and above the neap. The ſurface is carefully levelled by the plough, and rolled ſmooth and hard. It is then filled to the heighth of ſeveral inches with ſand taken from the edge of the ſea at low water, and the ſand is alſo drenched with ſea-water as the tide flows in. It then lies expoſed to the ſun and wind, which ſoon diſſipate the ſuperfluous water, and the ſurface of the ſand appears covered with a white efflorescence. It is then turned over frequently with a kind of ſhovel, changing the ſurface ſeveral times a day till the whole is thoroughly dry. This ſaline ſand is then carried to the ſheds, and the proceſs repeated with freſh ſand till a large quantity is collected, which generally employes the whole ſummer. To make the ſalt, the dry ſand is taken out of the ſheds and thrown into ſmall round pits about 2½ feet in diameter, and 12 inches deep, the bottoms of which are lined with hard rammed clay mixed with chopped ſtraw, to prevent the water from oozing through. The ſand is then covered with ſea-water, or with the weaker ley of former operations, and after ſtanding ſome hours is drawn off into reſervoirs or barrels, whence the evaporating pans are immediately ſupplied. The ſand is lixiviated a ſecond time, and this ley is reſerved for a freſh portion of ſand. The boilers are of lead, about 3½ feet ſquare, and 4 or 6 inches deep. They are heated with wood of any kind, or ſometimes with reeds, and a boiler of this kind is worked off in from two to three hours. The ſalt is raked out as it forms, and drained in hollow cones, as in other places. Three pans of this dimenſion yield together about 50lbs. of ſalt. The ſalt procured in this way is white and ſmall grained, but it is very apt to be damp, and is a weak-bodied ſalt little fit for preſerving animal food for any length of time.

In ſome northern countries ſome advantage is made of the effect of cold in concentrating brine, by freezing at firſt only the more watery part, of courſe leaving the unfrozen part proportionably richer in ſalt. The winters of this country are not cold enough in general for this purpoſe, but it is uſed occaſionally on the Baltic coaſts. The cold however muſt not be too intenſe, otherwiſe the brine itſelf freezes. Frozen ſalt water is not in hard ſolid maſſes like freſh water, but it is ſoft and crumbly or rotten. The efficacy of this method of concentrating brine is very conſiderable.

Though much of the French ſea-ſalt is very indifferent, the Dutch refine it into a very excellent ſalt, which is uſed in pickling the herrings for which this nation is ſo juſtly famous, and which trade is under the ſtricteſt inſpection as to the goodneſs of the ſalt, and the care to be taken in every ſtep of the buſineſs. It is not preciſely known whether the Dutch do any thing more than boil the ſalt again and evaporate ſlowly, except that it is the conſtant cuſtom when the brine begins to ſalt, to add a ſmall quantity of very ſour whey, which is found by experience to be a very important addition.

* * * *

It has been ſuppoſed by ſome eminent obſervers that when a conſiderable depth of brine not ſaturated, remains at reſt for a time, there is a gradual but inviſible ſubſidence of the ſalt, ſo that the lower part of the column of brine will be ſenſibly ſalter than the upper. To this has been attributed the increaſe of ſaltneſs in the ſea, in proportion to the depth whence the water is taken. With regard to land brine-ſprings, it is indeed certain that the deepeſt are uſually much the ſalteſt, but this may be readily accounted for from the conſtant infiltration of freſh water which almoſt always lies above the ſalt rock, and ſometimes in vaſt quantity. Hence it is neceſſary in moſt places (as in Cheſhire for example) to line the ſides of the brine well with very ſtrong planking, and even this cannot entirely keep out the freſh water, which always finds ſome way in.

But an experiment of Haller ſhews that there is actually a ſubſidence of ſalt, or at leaſt ſomething takes place which produces a ſimilar

[g] Journ. des Mines. No. 7, p. 61. and Ency. Meth. Arts & Metiers, Article *Salines*.

effect. For this purpose he made and fixed up vertically a tube of tinned iron, 33 feet high, and filled it with brine containing 12 per cent. of salt, and closed the top. In two months it was opened. Fifteen inches of liquid had oozed out, the brine at the surface (or 15 inches below the level when put in) gave only $9\frac{1}{2}$ per cent. of salt, at 11 feet lower it was nearly the same, but at the bottom, or 33 feet, it gave $12\frac{7}{8}$ per cent. This difference however is too small to promise any advantage in concentrating weak brines by mere subsidence.

The same excellent observer has given a series of accurate observations on the spontaneous evaporation of brine exposed to the weather in summer in reservoirs of a given dimension, at Aigle in the canton of Berne.[h] Though a mountainous country the climate is here warm enough for the vine and pomegranate. The heat in the middle of summer rises from 140° to 144° in the sun. To contain the brine a reservoir was made of the coarse marble of the country, the joints of which were lined with asphaltum to prevent leakage. This reservoir was covered with a light moveable roof, which was put up only in rainy weather. Another reservoir was also made of wood, but it is found that the soundest timber will not entirely stand the pressure of a column of salt water except of a few inches, for after a time the brine oozes through, and covers the outside with a stalactitical saline crust. The particulars of these experiments which were carried on with great attention for several years, need not be related at large, as they are calculated for a climate very different from ours. In general it may be observed that the utmost exhalation for a single day in summer, was found to be 3 lines or $\frac{1}{4}$ of an inch. Scarcely any thing exhaled in the winter months. From October to February (4 months) the entire exhalation was only 10 lines. In March, the average exhalation for the whole month was 15 lines; in April 35; in May 48; in June 44; in July 47; in August 35; in September 25, and in October 15. The mean exhalation from March to October therefore, was 261 lines, or $21\frac{3}{4}$ inches. These numbers however do not give accurately the relative exhaling power in the different months, for the brine as it becomes more and more condensed, parts with its water with much more difficulty, and the above experiments only give the continued loss by exhalation of the same brine for many months consecutively.

The quantity of salt yielded by spontaneous exhalation is nearly equal to that produced in experiments in the small way on a few pounds of brine, which is far from being the case in actual manufacture. The salt obtained thus gradually is large-grained, of an opake white, very hard and somewhat inclined to dampness, and not very readily soluble. The common salt on the other hand is semi-transparent, softer, and more readily soluble.

During the evaporation of brine in a boiling heat the vapour that rises is sensibly saline, and gives a saltish impregnation to wood and other porous matter which it meets with. It has been asserted that part of the acid also is separated in this heat and volatilized, leaving the salt therefore with a greater proportion of alkali, and to this has been attributed the inferior power of the small-grained salt in preserving provisions.

Though the inferiority be undoubted it does not appear that any very accurate experiments have been made on the relative quantities of acid in the large and small-grained salt, this hypothesis therefore is altogether doubtful. Neither does the large-grained salt owe its superior strength to any superior purity or freedom from the deliquescent earthy muriats, for the fine London basket salt is somewhat purer than the best Portugal bay salt, though the quantity of earthy matter in each is scarcely notable. On the whole it is more probable that the hardness of texture and slow solubility in water of bay or fishing salt (which it owes to the slowness of crystallization) is the chief cause of its superior efficacy.

Methods of procuring Soda by decomposition of Common Salt.

Muriat of soda being the most abundant of the neutral salts, and its alkaline base bearing for the most part a higher price in the market than potash, has been subjected to a vast variety of processes both on a small and large scale, with more or less perfect success, for the purpose of effecting its decomposition, so as to obtain the alkali separate, or at least only combined with carbonic acid. These different methods naturally divide themselves into two classes, the first containing those that aim at the immediate extraction of the alkali, and the second those that seek the same end, but by more complex means. Under the first class will be described the decomposition of salt by lime, by iron, by oxyd of lead, and by potash; under the second class will be mentioned the different methods of decomposing salt after it has been previously converted into sulphat of soda.

[h] Mem de l'Acad. for 1764.

It was Scheele[a] who first discovered in contradiction to the established laws of chemical affinity, that muriat of soda might be decomposed by means either of iron or quick-lime in an atmosphere considerably charged with carbonic acid. Thus if a plate of iron is dipped in a saturated solution of common salt, and then hung up in a cellar, a decomposition of the salt will be found to have taken place in the course of a few days; the surface of the iron will be studded with drops of a yellow liquor, consisting for the most part of muriat of iron, while the soda liberated from the muriatic and combined with the carbonic acid, will have assumed the appearance of small spicular crystals rising from the surface of those parts of the plate that are not occupied by the muriated iron. So in like manner if quick-lime be formed into a paste with a strong brine of common salt, and the mixture be placed in a cellar for some days, the surface of the lime will be covered with a light down of slender crystals of carbonated soda; these being removed they will be succeeded by a second similar efflorescence, and the second by a third. The decomposition in both these cases is attributed by Scheele, and apparently with great reason, to the efflorescent quality of carbonat of soda, which readily disposes it to rise from the surface where it is generated in spicular crystals, and thus separate itself from the muriat of iron or lime by which it would be again decomposed. This explanation of the fact derives additional force from the circumstance that muriat of potash is not decomposable either by lime or iron, probably because carbonat of potash, not being an efflorescent salt, is unable to separate itself from the rest of the mass. Vauquelin[b] seems disposed to attribute the decomposition of common salt by lime, to the formation of an insoluble muriat of lime with excess of base, but this appears to be disproved by an observation of Scheele, that if the residuum after the efflorescent salt has been collected be lixiviated, and the excess of lime in the solution be got rid of by means of carbonic acid, the remaining clear liquor will furnish an abundant precipitate of carbonated lime on the addition of the effloresced carbonat of soda, thus shewing that the solution contains muriat of lime in its ordinary state. Berthollet has shewn that even carbonat of lime, when in great excess, is capable of decomposing muriat of soda, more especially if straws or any other similar substances are stuck upright into the mass, to assist the efflorescent power of the soda, by offering a support on which it may concrete and escape the re-action of the muriated lime: this method is indeed considerably less expeditious than that discovered by Scheele, yet it seems to be the very mode employed by Nature at the Natron lakes of Egypt, as Berthollet has shewn in a very interesting report on this subject.[c]

Of the three modes of decomposing muriat of soda mentioned above, that by means of quick-lime is the only one that has been attempted on a large scale, but though superintended by so able a chemist as Morveau[d] it does not appear to have been attended with sufficient advantage to counterbalance the expence of time and fuel. The process employed differed in no respect from that of Scheele, except that the mixture after it had ceased to yield any more soda was re-calcined and again treated with a solution of common salt. It has been proposed as an improvement of this process, to mix with the lime and salt a sufficient quantity of clean sand to convert it into mortar, and then to line cellars or other excavations with it, in order to expose a larger surface to the action of the air. There is no doubt that the yield of carbonated soda would thus be greatly augmented, and it is not improbable where natural or artificial excavations could be conveniently obtained, that the increased product would more than equal the additional expence.

The possibility of decomposing common salt by means of litharge or any other of the oxyds of lead, was first ascertained by Mr. Turner, who obtained a patent for the discovery in the year 1780. His process is the following:[e] To ten parts of any of the oxyds of lead add five parts of muriated soda, previously dissolved in water; grind the whole together till the litharge becomes almost impalpable, and then let the mixture stand for twenty-four hours, in which time the lead will appear of a white colour: the mass, which will have acquired a tolerably solid consistence, must now be broken down in water and be well washed; the liquor will contain the alkali of the salt, and the white insoluble residue consists of the litharge combined with muriatic acid. This residue after being carefully lixiviated and dried, if exposed on a muffle or in any other suitable way to a calcining heat, acquires a yellow colour, varying in tint according to the temperature; this yellow muriat when ground up with oil and varnish in the usual manner, forms a pigment known by the name of *patent yellow*, and very extensively employed in coach-painting.

[a] Essays, p. 55. [b] Ann. Chem. xxxi. p. 10. [c] Mem. de l'Instit. de Cairo. [d] Ann. Chim. xix p. 102. [e] Repertory xii. p. 157.

A ſolution of muriated lead is readily decompoſable by ſoda, either cauſtic or carbonated; the explanation therefore of this ſeeming anomaly on which Mr. Turner's patent was founded, became an important chemical problem, and has exerciſed the abilities of Kirwan, Haſſenfratz, Berthollet, Vauquelin, and others. By the experiments of the laſt of theſe able chemiſts the difficulties have been cleared up, and the apparent contradiction has been reconciled to the general laws of chemical affinities.[f] He mixed together, by grinding in a mortar, ſeven parts of litharge and one of muriated ſoda, adding as much water as brought the whole to the conſiſtence of thin paſte; it was then ſtirred for ſeveral hours to facilitate the mutual action of the ingredients. By degrees the colour of the litharge became paler, its volume increaſed very conſiderably, and ſeveral additions of water were required to prevent it from forming a ſolid maſs: at the end of four days the chemical change appeared to be compleat, the litharge having acquired a white colour, the mixture was accordingly diluted with ſeven or eight parts of water and filtered. The clear liquor had an alkaline flavour, and when reduced by evaporation to $\frac{1}{10}$ of its bulk, afforded cryſtals of carbonated ſoda mixed with a little muriat of lead, and the common ſalt was intirely decompoſed. The reſidue on the filter when well waſhed and dried, was of a dirty yellow colour, and exceeded in weight the litharge employed by about $\frac{1}{8}$; by a gentle calcining heat its colour was changed to a fine lemon yellow, and its weight was diminiſhed by about 2.5 *per cent.* In pure water even when boiling it is ſcarcely ſoluble; but by digeſtion with cauſtic ſoda a conſiderable portion was taken up, and the reſidue aſſumed a dirty white colour, and was changed from a pulverulent conſiſtence to that of needle-form cryſtals. The ſoda ſolution was but little different in taſte from the pure alkali, but gave a very abundant black precipitate with hydroſulphuret of ſoda, a white precipitate with muriatic acid, and alſo with nitric acid, but this laſt was reſoluble in an exceſs of acid. If the yellow reſidue was treated with dilute nitric acid inſtead of ſoda, there remained an inſoluble portion of a white colour and cryſtalline texture, and the nitrous ſolution depoſited by gentle evaporation cryſtals of nitrat and muriat of lead.

From theſe facts it appears that litharge by the decompoſition of common ſalt, is converted into a ſub-muriat, or muriat with exceſs of baſe, and therefore differing very materially from the common muriat; that this ſalt though ſoluble in cauſtic ſoda is not decompoſable by it; and that the efficient cauſe of the decompoſition of common ſalt by litharge is the property of muriated lead to combine with an exceſs of baſe, by which the affinity of the acid for the alkali is counteracted; that the yellow colour which this ſub-muriat acquires by being heated, is occaſioned by the exceſs of baſe, ſince the common muriat exhibits no ſuch character; that to this exceſs is alſo owing the inſolubility of this ſubſtance in water; and finally that by the addition of nitric acid the ſub-muriat is decompoſed, being itſelf converted into muriat, and yielding its exceſs of oxyd to the nitric acid.

In confirmation of the opinion that the oxyd of lead decompoſes common ſalt only in conſequence of its being converted into a ſub-muriat, it may further be remarked, that the white precipitate depoſited by the action of cauſtic ſoda on the ſoluble muriat is not a ſimple oxyd as has been generally ſuppoſed, but a ſub-muriat, exactly ſimilar to that which we have been deſcribing.

It has been ſuppoſed by ſome chemiſts that the carbonic acid which litharge and moſt of the other oxyds of lead contain, has a conſiderable ſhare in effecting the decompoſition of muriat of ſoda, this however has been denied by other chemiſts, and particularly by Vauquelin, who affirms that carbonat of lead and muriat of ſoda have abſolutely no action whatever on each other. This being the caſe it follows that litharge, minium, &c. are the worſe calculated for decompoſing common ſalt in exact proportion to the carbonic acid which they contain: hence ariſes the propriety of mixing quick-lime with the litharge, in order to abſorb its carbonic acid, and thus expedite its action. By availing himſelf of this addition M. Curadeau[g] found that 30 parts of litharge and 4 of quick-lime, were able to effect a total decompoſition of 10 parts of muriated ſoda. But even with this improvement and with every attention to economy, it does not appear that this method of ſeparating the ſoda from ſea-ſalt can be attended with much profit on a large ſcale: the demand for the yellow ſub-muriat is very limited, and the white ſub-muriat although its colour is very good, is not poſſeſſed of ſolidity enough when ground up with oil to be employed as a ſubſtitute for common white lead: it would there-

[f] Ann. Chem. xxxi. p. 1.

[g] Ann. Chem. xiv. p. 15.

fore be neceffary in a large eftablifhment to reduce moft of the fub-muriat to the ftate of metallic lead, at a confiderable expence of fuel and labour, and of lofs by volatilization, &c. and then by a fecond procefs to re-calcine the lead before it could be brought again into fervice.

Another method propofed for the decompofition of common falt, and which feems to have attracted confiderable notice among the German chemifts, is founded on the fuperior affinity of potafh over foda, for muriatic acid; if therefore to a folution of common falt there be added a fufficient quantity of potafh, either cauftic or carbonated, an exchange of bafes will take place, and the fluid will yield by evaporation and cryftallization carbonated foda and muriated potafh. But this mode of proceeding is by no means fo eafy and fimple in practice as in theory, as may be feen in a memoir on the fubject by Weftrumb,[h] from which the following account is extracted.

Diffolve 20lbs of common falt in 30 quarts of water, and add to the folution 25 lbs of purified potafh or pearlafh, then evaporate the liquor till three or four ftrong pellicles have formed in fucceffion on its furface, each in turn being broken down by any convenient inftrument: the liquor being now transferred into another veffel, is to be kept at the temperature of about 60° Fahr. as long as it depofits any cryftals. The falt thus formed is a mixture of muriat and fulphat of potafh (the latter pre-exifting in the potafh) which may be feparated from the liquor by paffing it through a filter made of flannel. The filtered folution after ftanding about an hour longer, will depofit more muriat of potafh, mixed however with carbonated foda. Thefe falts being removed and the refidual liquor being placed in a cellar or any other place fufficiently cold, will yield a copious depofit of cryftallized carbonated foda. The fupernatant liquor being again treated as at firft, affords a fecond crop of muriated potafh, and afterwards by refrigeration, of carbonated foda: and thefe two proceffes are repeated in fucceffion till the mother water refufes to yield any more falt. The different parcels of muriated potafh are now to be mixed, and diffolved in boiling water, which is afterwards to be evaporated to one half, during which a confiderable depofit of muriated potafh will take place: the fupernatant liquor being transferred to another veffel and expofed to the cold will depofit a confiderable part of the carbonated foda which it contains; a fecond evaporation and cooling will feparate a further portion of the fame, after which it is not worth while to purfue the procefs any further. The carbonated alkali thus obtained is to be mixed with the reft and the whole diffolved in an equal weight of water; the folution by cooling depofits a large quantity of carbonated foda in a ftate of confiderable purity; the remaining liquor being evaporated will generally yield more or lefs of muriated potafh while it cools, and then by expofure to a low temperature a fecond crop of carbonated foda may be obtained: by again repeating on the remainder the proceffes of evaporation and cooling a fecond crop of muriated potafh and a third of carbonated foda are procured; but this laft being confiderably lefs pure than the two preceding crops of carbonated alkali, is to be kept apart.

All the preceding operations are compleated in 12 or 14 days, and the average produce is 20 lbs of pure cryftallized and 2½ lbs of impure cryftallized carbonat of foda. The amount of muriat of potafh is not mentioned by Mr. Weftrumb. If the above is a true reprefentation of the mode of carrying on the decompofition, and of the amount of produce obtained (which there feems no reafonable caufe to doubt) it is obvious that it can only be performed with profit in countries far remote from communication with the fea, where potafh and common falt are very abundant and labour extremely cheap: it is alfo manifeft that when carried on in the large way the feparation of the foda from the other ingredients muft be even more difficult than is reprefented by M. Weftrumb, on account of the great accumulation of mother water; and after all that can be done by cryftallization and evaporation, by far the greater part of the foda will be loft. Common falt contains 53 *per cent.* of alkali; and carbonated foda in cryftals contains 22 *per cent.* of the fame, whence it appears from Mr. Weftrumb's own proportions that no more than 21½ lbs of carbonated foda are obtained from materials that contain 48 lbs.

But the moft eligible methods of obtaining the alkali from common falt are thofe by which it is firft converted into Glauber's falt previoufly to the extraction of the foda. It will be proper therefore firft to confider the various fources from which fulphat of foda may be obtained by the decompofition of fea falt.

It is produced in the moft economical manner as a refidue in various chemical manufactures,

[h] Journ. de Phyf. xxxv. p. 195.

ſuch as the preparation of ſal ammoniac, of muriatic acid, and of oxymuriatic acid for the bleacheries. In ſituations however where theſe reſidues are not to be obtained, it muſt be prepared by the direct decompoſition of muriated ſoda: the two cheapeſt methods of effecting this appear to be by means of gypſum and of iron pyrites.

The firſt of theſe is carried on in the following manner. Take any quantity of calcined gypſum and ¼ of its weight of common ſalt; mix them accurately by grinding, or in any other convenient way, then add to the powder a ſufficient quantity of water and make it up into balls three or four inches in diameter. When theſe balls are dry, let them be calcined for five or ſix hours in a reverberatory furnace, then break them down into pieces no larger than a hazle nut, and lixiviate them with cold or warm water: the liquor when boiled to a pellicle affords by cooling cryſtals of Glauber's ſalt.

[1]The ſecond method, or that by means of pyrites is thus accompliſhed. Take 100 lbs. of common pyrites and reduce it to fine powder, then add 40 lbs. of common ſalt; mix the two ingredients well together and expoſe the maſs for 60 hours to a roaſting temperature; a copious diſengagement of muriatic and ſulphureous acids will take place, and the maſs will ſtill continue pulverulent, but of a browniſh red colour, and reduced in weight to 107½ lbs.

Being now lixiviated and the liquor boiled down to a proper conſiſtence, there will be depoſited about 45 lbs. of cryſtallized ſulphat of ſoda, and the mother water evaporated to dryneſs will leave between 8 and 9 lbs. of a ſaline maſs conſiſting of ſulphat of ſoda, muriat of iron, and a little undecompoſed common ſalt. The inſoluble reſidue conſiſts of ſulphuret of iron with exceſs of oxyd, weighing 67½ lbs. in a highly favourable ſtate for vitriolization.

A conſiderably greater quantity however of ſalt can be decompoſed by a given weight of pyrites if there be added to the mixture either charcoal, pitcoal, or peat, but eſpecially the latter. For this purpoſe 100 lbs. of pulverized pyrites and 300 lbs. of dried peat being well mixed together, 65 lbs. of ſalt diſſolved in water are to be added, and the whole maſs after being carefully tempered is to be made up into balls. Theſe balls when dry are to be placed in a reverberatory furnace with a little fuel juſt to kindle them, after which they will burn of themſelves; the combuſtion is to be kept up as gentle as poſſible till the incineration is compleat, and then the aſhes being lixiviated and the liquor boiled down in the uſual manner, there will be procured 70 lbs. of cryſtallized ſulphat of ſoda, and 17 lbs. of dry ſalt, conſiſting of muriat of iron and ſulphat of ſoda, from evaporating the mother water.

The ſulphat of ſoda whether obtained from the ſources above pointed out or from any other, may be decompoſed ſo as to afford its alkali in a ſeparate ſtate by either of the two following methods, the ſucceſs of which has been proved by experiments on a very large ſcale.

1. *Decompoſition of Glauber's ſalt by the combined action of chalk and charcoal.*

Take 1000 lbs. of calcined Glauber's ſalt and 550 lbs. of charcoal, and mix the two ingredients accurately together by grinding; when the mixture appears compleat add by degrees 1000 lbs. of waſhed chalk, and continue the grinding till this alſo is mixed with the other materials. Now let a reverberatory furnace be lighted, and as ſoon as it is red hot let it be charged with 4 or 500 lbs. (more or leſs according to the ſize of the furnace) of the above mixture, and cloſe the door. During the firſt part of the proceſs, while the materials are yet pulverulent the flame muſt be kept as gentle as poſſible leſt it ſhould carry part of the powder up the chimney; but as ſoon as the matter begins to clot the flame may be increaſed. At this time the maſs muſt be carefully worked about with an iron rake in order to expoſe freſh ſurfaces to the action of the flame. When the whole has acquired a paſty conſiſtence jets of inflamed ſulphuretted hydrogen will be perceived to iſſue from every part, accompanied by a moderate but very perceptible exploſion and efferveſcence; and during the whole of this ſtage of the proceſs the rake muſt be uſed very vigorouſly in order to expedite the diſengagement of the gas. When the jets of flame ceaſe, and the matter becomes nearly fluid the rake may be withdrawn, and a bar of cold iron is to be introduced from time to time in order to judge of the progreſs of the operation by the ſample that adheres to the end of it: if this cracks as it grows cold and preſents an uniform granular texture the heat has been continued long enough, and the matter muſt then be ſpeedily withdrawn leſt it ſhould be fritted by the further action of the fire. The flame being accordingly turned off for a few minutes, the maſs returns to a paſty conſiſtence and is withdrawn from the furnace by means of the rake. As ſoon as it

[1] Pelletier Mem. de Chem. II. p. 208, or An de Chem. xix.

becomes solid by cooling, it is to be broken into moderate sized pieces and kept for some days in a damp cellar, where it imbibes a considerable quantity of water and carbonic acid, falls to powder and at the same time parts almost entirely with the sulphuretted hydrogen to which its hepatic smell and flavour when recent are owing. It may now be brought to market, without any further preparation, or the alkaline part may be extracted and sold separately.

In order to separate the alkaline from the earthy part lixiviation with cold water must be had recourse to: the clear liquor by evaporation to a pellicle and subsequent cooling, deposits crystals of carbonated soda, and the mother water, consisting chiefly of semicaustic soda, must be boiled down to dryness and afterwards calcined till it is as white as pearlash, in which state it is well fitted for the glass makers.

500 lbs. of raw materials treated as above described afford 276 lbs. of rough soda, of which 100 lbs. yield by lixiviation 37 lbs. 8 oz. of crystallized carbonat, and 23 lbs. 2 oz. of dry semicaustic soda, with a small admixture of sulphuret of lime and of other salts accidentally contained in the original sulphat.

2. *Decomposition of Glauber's salt by means of iron and charcoal.*

	lbs.	
Take	200	Calcined Glauber's salt
	40	Powdered charcoal
	65	Clippings of iron plate or old iron
	22	Charcoal in the state of small coal
	327 lbs.	

Having mixed the sulphat of soda with the powdered charcoal, let it be introduced into the reverberatory furnace and treated for the first hour exactly as described in the foregoing process: then bring the mixture to compleat fusion and add 40 lbs. of the clippings, stirring the materials well at the same time with an iron rake in order to mix them more compleatly. In a short time after, the matter which was at first quite fluid will become pasty, accompanied with much foaming and boiling till the clippings are dissolved: as soon as this takes place, 16 lbs. of small coal must be stirred in, which will immediately excite the disengagement of sulphuretted hydrogen mentioned in the former process. When this appearance begins to slacken, the remaining 25 lbs. of clippings and 6 lbs of small coal are to be added in succession, and the stirring is to be diligently continued till the jets of inflamed gas almost cease: when this happens, the matter still fluid is to be run into moulds of sand where it solidifies.

The rough soda thus prepared weighs 215 lbs. is of a blackish brown colour which becomes still darker by the contact of the air: when broken it has a kind of metallic lustre and a close striated texture. To the taste it is caustic and hepatic: by exposure to a moist atmosphere it becomes covered with a yellow efflorescence, and quickly falls to powder with a considerable disengagement of heat and sulphuretted hydrogen; at the same time it absorbs carbonic acid and water so as to increase in weight by an exposure of about 20 days in the proportion of 5 to 8.

From the 215 lbs of rough soda thus obtained and increased by absorption of air and moisture to 344 lbs. may be obtained by lixiviation and crystallization 152 lbs. of carbonated soda, and the uncrystallizable mother water will afford by evaporation about 47 lbs. of semicaustic soda mixed with a little charcoal, sulphuret of iron and other impurities. The insoluble residue weighs about 185 lbs. and is sulphuret of iron with a little charcoal in a state highly favourable for vitriolization.

Muriat of Ammonia. See Sal Ammoniac.

Muriat of Lime.

This earthy salt was first known in chemical manufacture as the residue from the distillation of carbonat of ammonia by chalk and muriat of ammonia. It is also found native frequently, but in small quantities, in a great variety of saline springs, but never entering into any solid mineral.

To procure it pure any quantity of pure chalk or white marble is to be dissolved in pure muriatic acid to saturation, and the clear fluid evaporated to a thick syrupy consistence, when by cooling it will congeal into a yellowish transparent saline mass, of a striated texture. This salt may also be procured in regular crystals in the form of six sided prisms terminated by six-sided pyramids, but it is not easy to crystallize this salt. Pelletier succeeded by exposing a concentrated solution to very gradual evaporation in a warm and dry air. Beaumé finds the same crystallization when the solution is long kept in bottles.

This salt is one of the most deliquescent of all the known salts, so that the crystals kept exposed to the air, or even in a bottle but slightly stopped, soon resolve into a dense yellowish liquid resembling oil in appearance, and called by the older chemists *oil of lime*. This

may be again brought to the ſame cryſtallized maſs by evaporation and cooling.

Muriat of lime has no ſmell. The yellowiſh colour which it has is probably owing to the ſmall quantity of iron which is contained in almoſt every calcareous earth, and alſo in common muriatic acid. The taſte is acrid, bitter, and nauſeous.

The ſolubility of this ſalt is indefinite in a warm temperature, for it readily melts in its water of cryſtallization when heated. Cold water will diſſolve twice its weight, and hence the ſolution muſt be extremely concentrated before the ſalt will ſeparate in a ſolid form by cooling. If a ſolution ſo far concentrated as to cryſtallize by cooling be poured hot into a bottle and immediately corked, it will remain fluid for ſome time when cold, if quite at reſt, and then when the cork is drawn and the bottle ſhaken, the whole will ſolidify in a few ſeconds with the evolution of ſo much heat that the bottle cannot be held in the hand. This experiment however does not always ſucceed, nor with ſo much certainty as with Glauber's ſalt.

Muriat of lime heated *per ſe* firſt liquefies and as it dries puffs up extremely and turns to a white ſaline maſs ſtill deliqueſcent. If the heat be continued it parts with a portion of its acid but not the whole. Beaumé has the following analytical experiment on the ſubject. Four ounces of muriat of lime heated for three hours in a fire gradually raiſed to redneſs, gave an ounce of good colourleſs muriatic acid, and the maſs remaining in the retort was white, ſpongy, and ſaline. Three ounces of cold water were added which immediately acquired a boiling heat, and on adding more water and filtering, a clear ſolution of muriat of lime was obtained, and a quantity of inſoluble earth left behind. This liquor evaporated to dryneſs and diſtilled in a very ſtrong heat till the retort was ſoftened, gave nothing more than a very ſlightly acidulous water. Muriat of lime when heated in an open crucible parts with more of its acid, but never with the whole. The reſidue from the diſtillation of volatile alkali is phoſphoreſcent when heated. It is compoſed of muriat of lime with exceſs of lime, and probably alſo of ſome undecompoſed chalk. It forms *Homberg's phoſphorus.*

Muriat of lime is very ſoluble in alcohol. When rectified, alcohol diſſolves its own weight.

Pelletier relates a curious and unaccountable phenomenon. If carbonic acid is paſſed through a ſolution of muriat of lime the whole preſently changes into a ſubſtance ſo ſolid as to require a ſtrong ſtroke of the hammer to break it.

The ſulphuric acid decompoſes this ſalt, and owing to the ſparing ſolubility of the ſulphat of lime and the high ſolubility of the muriat, if ſulphuric acid is poured into a concentrated ſolution of the latter ſalt, the whole immediately turns to a white ſolid maſs of calcareous ſulphat.

The compoſition of this ſalt is thus given by Kirwan: fifty parts of pure lime ſaturated with muriatic acid, form 100 of the muriat when heated to redneſs, and 100 parts of muriat in this ſtate therefore contain 50 of lime, 42 of acid, and 8 of water.

This ſalt has ſome not unimportant uſes in chemiſtry. From its great tendency to deliqueſcence, it is valuable in the experiments on gaſes to abſorb the moiſture from them. For the ſame reaſon alcohol is brought to a very high degree of rectification when diſtilled off the dry muriat. The cryſtallized muriat alſo affords the cheapeſt and moſt powerful ſubſtance as a freezing mixture, to produce the moſt intenſe degrees of artificial cold, as mentioned under the article *Freezing.*

MURIAT OF BARYTES.

This ſalt is never found native. It may be prepared by diſſolving either the natural or artificial carbonat of barytes in muriatic acid, or from ſulphuret of barytes and muriatic acid, or from muriat of lime and ſulphat of barytes, all of which methods are deſcribed under the articles *Barytes* and *Carbonat of Barytes.* Muriat of barytes cryſtallizes readily from a hot concentrated ſolution by cooling, or by ſlow evaporation. The cryſtals are large, of an opake white, and generally in octogonal tables truncated at the angles. The taſte is acrid and aſtringent. It is one of the heavieſt ſalts known, and is readily diſtinguiſhable from moſt other ſalts by its external properties.

This ſalt is not deliqueſcent, nor in any way alterable in the air. When heated it loſes its water of cryſtallization, but none of its acid. In a ſtrong fire it melts, but is not in any other way altered. About five parts of cold water diſſolve one part of the cryſtallized ſalt, and boiling water ſomewhat more, but to cryſtallize it readily by cooling, it muſt be conſiderably concentrated by evaporation. It contains 64 of barytes, 20 of acid, and 16 of water of cryſtallization.

Sulphuric acid and every ſoluble ſalt containing it decompoſes muriat of barytes, and forms an inſoluble ſulphat of barytes, and this takes

place with ſuch minute quantities as to render the muriat (as well as the other ſoluble ſalts) of barytes a moſt valuable teſt for ſulphuric acid in any form. Nitric acid alſo decompoſes this muriat, and if it is much concentrated a white precipitate of nitrat of barytes falls down, owing to the more ſparing ſolubility of the nitrat in water than of the muriat. But it is diſſolved by adding more water, by which it may be readily diſtinguiſhed from the ſulphat.

Muriat of barytes is uſed as a teſt for ſulphuric acid in chemical experiments. It has alſo been employed in medicine, and like all the other ſoluble barytic ſalts it is a powerful poiſon in large doſes.

Muriat of Strontian.

This ſalt is prepared by diſſolving ſtrontian or its carbonat in muriatic acid. The modes of procuring ſtrontian will be found under the articles *Strontian* and *Carbonat of Strontian*. The ſalt cryſtallizes in long needles, very tender and eaſily broken, the form of which it is not eaſy to determine, but the ſtriking difference in the appearance of muriat of ſtrontian and muriat of barytes will readily enable the chemiſt to diſtinguiſh theſe ſalts, which in other reſpects have many properties in common.

Muriat of ſtrontian is one of the moſt ſoluble of all the known ſalts. A hundred parts of the cryſtallized ſalt required but 75 of water at a moderate temperature, and when heated it diſſolves in its own water of cryſtallization. Alcohol when boiling alſo diſſolves a large quantity, but the greater part is again ſeparated by cooling. The alcoholic ſolution when ſet fire to, burns with a beautiful crimſon flame, which is a very uſeful teſt for ſtrontian. The taſte of the ſalt is cooling at firſt, and afterwards rather acrid, but not auſtere like muriat of barytes, nor bitter. It is not poiſonous. This ſalt is not deliqueſcent. When heated it loſes its water of cryſtallization, but none of its acid. Its component parts according to Vauquelin, are (in the cryſtallized ſtate) 36.4 of ſtrontian; 23.6 of acid; and 40 of water.

It is not applied to any uſe.

Muriat of Magnesia.

Magneſia diſſolves in muriatic acid with great eaſe, forming a bitter nauſeous ſalt which cannot but with extreme difficulty be brought to cryſtallize, but when evaporated nearly to dryneſs becomes a gelatinous, ſhapeleſs, deliqueſcent maſs. It is found abundantly in nature, particularly in ſea-water, to which this owes its bitter nauſeous taſte. It alſo often accompanies common ſalt in the water of inland brine ſprings.

This ſalt is extremely ſoluble, requiring only its own weight of cold water. Boiling water takes up much more, ſo that a hot ſaturated ſolution on cooling coagulates to a gelatinous maſs.

Muriat of magneſia is compleatly decompoſable by heat, the whole of the water of cryſtallization and the muriatic acid flying off and leaving the magneſia pure. In this reſpect it differs from muriat of lime, with which it is often mixed, ſo that it affords an uſeful way in analyſis of ſeparating theſe earths, which has ſometimes been adopted. After calcining the two ſalts, therefore, muriat of lime and pure magneſia are left, which mere ſolution in water will ſeparate. As however muriat of lime is partially decompoſable by the ſame method, it probably would require a repetition of the calcination of the reſidue with freſh acid to ſeparate the earths compleatly.

Muriat of magneſia is readily decompoſable by the fixed alkalies and the alkaline earths. With ammonia, only a part of the earth is ſeparated in a moderate heat, and the remainder unites with the undecompoſed portion into a triple ſalt, the *muriat of magneſia with ammonia*, or *ammoniaco magneſian muriat*, which will be preſently mentioned.

The ſaturated carbonat of ammonia (deſcribed under the article *Carbonat of Ammonia*, and made by expoſing the pungent carbonat to the air for ſome hours) produces no precipitate whatever with muriat of magneſia, owing to the exceſs of carbonic acid, till this exceſs is driven off by heat.

Muriat of magneſia is compoſed according to Bergman, of 41 of magneſia, 34 of acid, and 25 of water. It is very ſoluble in alcohol.

Ammoniaco Magnesian Muriat.

This ſalt has been particularly deſcribed by Fourcroy,[a] in a valuable memoir on the triple magneſian ſalts, of which the following are the leading facts: 144 grains of carbonat of magneſia (containing 50 grains of magneſia) were diſſolved in muriatic acid, to which was added 72 grains of liquid ammonia, which cauſed a precipitate which, collected, waſhed and dried, weighed 3¼ grains. Seventy-two grains more of ammonia were added, which gave a further precipitate of 7 grains, though the former ſupernatant liquor was ſtrongly ammoniacal. Another doſe of 144 grains of ammonia gave a further precipitate of 14 grains, after which no further

[a] Ann. Chem. tom. 4.

addition of ammonia produced any precipitate. Thus only 24¼ grains, or one-third of the magnesia could be separated by any addition of ammonia, though the quantity of the latter was more than sufficient to saturate the muriatic acid. The remaining liquor yields by slow evaporation small polyhedral crystals, which have a bitter and ammoniacal taste, and are the *muriat of magnesia with ammonia*. The composition of this salt is inferred from the quantity of magnesia separated from the solution in the above-mentioned experiment: the 24¼ grains of precipitated magnesia saturated with muriatic acid and evaporated slowly, so as to become a confusedly crystallized mass, produced 98 grs. of muriated magnesia; hence the 48 grains of magnesia remaining in the solution would produce about 196 grs. of muriat, which remained in the triple salt. Then as 24½ grs. of magnesia were displaced by the ammonia, it is estimated that as much ammonia remains in the triple salt as is necessary to saturate as much muriatic acid as will saturate 24¼ grains of magnesia. From these data M. Fourcroy estimates the proportion of this triple salt to be 73 *per cent.* of muriat of magnesia, and 27 of muriat of ammonia. It would be easy however to shew that these data are far from sufficient, and it does not appear that they have been confirmed by analysis.

This triple salt may also be formed by the mixture of concentrated solutions of muriated ammonia and muriated magnesia, whereby the salt readily separates in small crystals. Magnesia agitated with a cold solution of muriated ammonia will also produce the salt.

The ammoniaco-magnesian muriat is readily decomposable by heat, the muriat of ammonia becomes volatilized, the whole of the muriatic acid flies off, and the magnesia alone is left.

This salt is not deliquescent as the simple muriat of magnesia is: it dissolves in six or seven parts of cold water, and in less when hot. It is obviously less soluble than either of the muriats of which it is composed, since it separates in crystals when the solutions of each are mixed.

Muriat of Alumine.

This salt is never found native. It is prepared by boiling muriatic acid on alumine for a considerable time, whereby a solution is effected which is always acidulous and has a very styptic austere taste. When evaporated to a thick consistence it takes a gelatinous form, but cannot be crystallized but with extreme difficulty.

This salt is very soluble in water. Like the muriat of magnesia, it parts with the whole of its acid by heat, and the alumine remains pure. The salt when brought to a gelatinous consistence, is extremely deliquescent in the air.

It is not applied to any use. According to Richter, 21.8 grains of alumine gave 100 of the muriat, evaporated so as to become sensibly dry.

Muriat of Zircon, &c.

(*For the other Muriated Earths, see these Earths respectively*).

MURICALCITE. See Bitterspath.

MUSCLE, or Muscular Fibre.

The chemical analysis of muscular fibre will be found under the articles Fibrin and Blood.

N

NACRE, or Mother of Pearl.

This term is applied to that beautiful natural white enamel which forms the greater part of the substance of the oyster-shell, particularly the pearl-oyster. Its chemical composition will be described under the article Shell.

NADELSTEIN. See Titanium.

NAPTHA. See Bitumen.

NATRON, is a term commonly applied to *Soda*, and particularly its *Carbonat*.

NEPHRITE. [a]

Of this mineral there are the two following subspecies.

1. *Subsp.* Common Nephrite or Jade. *Gemeiner Nephrit*, Wern. *Nephrite commun*, Broch.

Its colour is a somewhat dark leek-green verging to blue, or greenish or bluish white. It occurs massive and in detached rounded pieces. The smooth external surface is glimmering with an oily lustre; internally it is dull except when mixed with fibres of asbest and scales of talc. Its fracture is coarse splintery and sometimes obscurely fibrous. Its fragments are indeterminately angular. It is more or less translucent; it is hard, difficultly frangible and greasy to the touch. Sp. gr. of the Oriental 2.97 to 3.04, of the Swiss 3.31 to 3.38.

Nephrite by exposure to a mo[illegible] be-comes more brittle and semi-tr[illegible] fusible before the blowpipe [illegible] into a white semi-transparent [illegible].

Of the geological history o[illegible]

[a] Emmerling, Kirwan, Jameson, Brochant.

thing certain is known. It is found in China and India, in Switzerland, Piedmont and Tyrol.

It is difficult to saw or cut, and even when polished has a muddy appearance: its great toughness however enables the artist to fashion it into works of great delicacy. It is much prized by the Hindoos and Chinese, by whom it is made into talismans and idols, and by the Turks, who form it into sword and dagger handles.

2. *Subsp.* Axestone. *Beilstein*, Wern. *Pierre de Hache*, Broch.

Its colour varies between deep bluish and yellowish green, and sometimes passes into olive. It occurs in mass: internally it is strongly glistening with somewhat of a resinous lustre. Its fracture in the great is slaty, and in the small, splintery. Its fragments are tabular. It is translucent, and in hardness and toughness approaches nearly to the preceding subspecies.

Its natural situation appears to be in beds of argillaceous schistus.

It occurs in South America, in New Zealand and other islands of the Pacific ocean, where it is made by the natives into hatchets, tomahawks and other instruments. It is also found in Corsica, Switzerland and Saxony.

Nephrite appears to be closely connected with whetstone slate and indurated talc.

NEUTRAL SALTS. See Salts.

NICKEL. *Nikkel*, Germ, *Nikel*, Fr.

Nickel is a yellowish white semi-malleable metal, difficultly fusible, attractible by the magnet, soluble in nitric acid to which it gives a green colour, and when in the state of oxyd, soluble in ammonia, to which it gives a blue colour.

§ 1. *Ores of Nickel.*

Sp. 1. Copper Nickel. *Kupfer Nikkel*, Wern.

Its colour is pale copper red with a yellowish or greyish tint. It occurs massive and disseminated, sometimes though rarely reticular, arborescent or botryoidal. It is more or less shining with a metallic lustre. Its fracture is imperfectly conchoidal, passing into coarse grained uneven (this latter variety possesses the least lustre). Its fragments are indeterminately angular sharp edged. It sometimes occurs in granular or curved lamellar distinct concretions. Its hardness is considerable for it gives fire with steel, disengaging at the same time a strong arsenical odour. It is brittle, but difficultly frangible. Sp. gr. 6.6.

Before the blowpipe it gives out an arsenical vapour, and then fuses though not very easily into a dark scoria mixed with metallic grains. It appears to consist essentially of nickel and arsenic, but it also contains sulphur, iron, cobalt, copper, and not unfrequently bismuth and silver.

It occurs in veins both in primitive and stratified mountains accompanied by various ores of cobalt and silver, and by heavy spar, calcareous spar, brown spar, and quartz.

It is found most abundantly at Joachimsthal in Bohemia, Schneeberg, Freyberg and Annaberg in Saxony; and Andreasberg in the Hartz; it is also met with in Cornwall in England, at Allemont in France, in Stiria, in Arragon in Spain, and Kolywan in Siberia.

Sp. 2. Nickel Ochre. *Nikkel Okker*, Wern.

Its usual colour is apple green, passing to grass-green and greenish white; when moist the colour is considerably deepened. It occurs disseminated, and as a superficial covering on copper nickel and the ores of cobalt. It is composed of loose or slightly cohering pulverulent particles. It is meagre to the touch and is light.

It is infusible *per se* by the blowpipe, when melted with borax this latter acquires a hyacinthine colour and metallic globules are produced. It is often in part soluble in water, but this arises from an admixture of sulphat of nickel, which may thus be separated from the proper ochre.

It is found in the same places and situations as the preceding species.

§ 2. *Analysis of Ores.*

Copper nickel though not consisting essentially of more than two or three ingredients may yet casually contain a considerable variety of other substances as has been shown above. In giving therefore a formula for its analysis it will be advisable to consider it in its most compound form. Hence we shall suppose it to contain nickel, arsenic, sulphur, copper, iron, cobalt, silver, and bismuth, besides quartz and alumine.

1. The ore being ground to an impalpable powder must be digested with nitric acid considerably diluted, nitrous gas will be given out, and by two or three digestions every thing soluble will be taken up.

2. The insoluble portion, consisting for the most part of sulphur and silex, is to be dried, weighed, and then heated; the *sulphur* (*a*) will burn off, and its amount may be ascertained by the difference of weight before and after ignition. The residue after being boiled in a little nitrous acid is pure *silex* (*b*).

3. Add together both the nitrous solutions nearly saturate the liquor with pure soda, eva-

porate it considerably and then pour the solution into cold distilled water, by which the oxyd of *bismuth* (*c*) will be precipitated.

4. To the filtered solution add muriat of soda drop by drop as long as any precipitate falls down; this is muriat of *silver* (*d*).

5. Now evaporate the solution nearly to dryness, and boil it with strong nitric acid as long as any nitrous gas is given out: during the process red oxyd of *iron* (*e*) will be precipitated.

6. Having removed the oxyd of iron, nearly saturate the liquor with soda and pour in nitrat of lead as long as any *arseniat* of lead (*f*) is precipitated, which separate by the filter.

7. The nitrous solution being now decomposed by carbonated soda, and the washed precipitate digested in liquid ammonia, oxyd of *iron* (*g*) mixed with *alumine* (*h*) will be left behind, which may be separated in the usual way by caustic fixed alkali.

8. The ammoniacal solution is to be slightly supersaturated with nitric acid, and a bar of iron being immersed in it will separate the *copper* (*i*): after which the liquor is to be decomposed by carbonated soda and the precipitate again digested in ammonia, that the iron used for separating the copper may be got rid of.

9. The solution containing now only nickel and cobalt, is to be treated according to Mr. R. Phillips's [a] method, as follows. Evaporate the liquor till the excess of ammonia is driven off, which may be known by the vapour ceasing to discolour moist turmeric paper: then *largely* dilute it and pour in pure potash or soda as long as any precipitation takes place; what falls down is oxyd of *nickel* (*k*).

10. The *cobalt* (*l*) alone remains in solution, and may be readily separated by accurately saturating the liquor with nitric acid and then adding carbonated soda.

The above general mode of proceeding is also applicable to the analysis of nickel ochre, except that it should first of all be digested in water to dissolve out any sulphat of nickel which it may accidentally contain.

Nickel is not applied to any use, and therefore no attempt has been made in the large way to reduce its ores. The most satisfactory method of performing this in the laboratory on small quantities is the following.

a Dissolve the ore in dilute nitric or nitro-muriatic acid, and then stir into the clear solution a quantity of finely pulverized charcoal about equal in weight to the ore dissolved: evaporate the mixture to dryness and put it into a bellying cylindrical crucible with the mouth loosely closed with a bit of charcoal or an earthen-ware stopper. Place the crucible in a wind furnace and give it a full red heat as long as any arsenical vapours are disengaged: if this is carefully performed nearly the whole of the arsenic will be got rid of in a quarter of an hour or twenty minutes, far more effectually than by several hours roasting in the usual method. Now empty the contents of the crucible upon an earthen test, and by a gentle red heat with access of air burn off all the remaining charcoal.

b Transfer the contents of the test to a flask, and digest them with dilute nitric acid as long as any thing is taken up. Then boil the filtered solution with a little more acid in order to acidify any arsenic that may yet remain: this being done, saturate the liquor with soda and add nitrat of lead till it ceases to give a precipitate.

c Having separated the arseniat of lead, add to the clear liquor a little muriatic acid and boil it with a bar of zinc: the supernatant deep green liquor will now contain only the oxyds of zinc, cobalt and nickel.

d Decompose the solution by a carbonated alkali and digest the washed precipitate in ammonia, by which the zinc will be left behind; and then separate the oxyd of nickel according to Mr. Phillips's method already described.

e Mix the oxyd of nickel with glass of borax and expose it in a crucible with a little carbonaceous matter to the highest heat of a powerful furnace; a reguline button will thus be produced which is pure nickel.

§ 3. *Physical and Chemical properties of Nickel.*

The colour of nickel is a dull yellowish white: its fracture is foliated; it is brittle, yet not so much so as to prevent it from undergoing a slight extension under the hammer. Its sp. gr. is = 8.51. It is strongly attracted by the magnet.

These are the characters of the pure regulus as obtained by Mr. Phillips according to his process, the efficacy of which there seems no reason to suspect. M. Richter however has recently published a memoir on this metal,[b] in which he claims for it the rank of a noble one, and the characters of which according to him are the following. Its colour is between silver and tin white: it is not oxydable by exposure to the atmosphere: it is malleable either hot or cold, and by laminating may be reduced into leaves no thicker than $\frac{1}{16}$ of an inch. Its sp. gr.

[a] Phil. Mag. xvi. p. 312.

[b] Van Mons Journ. de Chim. vol. vi. or Phil. Mag. xxiii. p. 137.

when fused is = 8.279, and when hammered = 8.666. It requires for its fusion a heat fully equal to that for the fusion of manganese. It is very difficultly oxydable even at a white heat: it is not only attractible by the magnet but is capable of acquiring magnetic polarity. Some of the reguli of this metal obtained by Bergman also exhibited nearly the same properties, but from the mode of reduction pursued in both cases it appears almost certain that Richter's pure regulus is in fact an alloy of this metal with iron.

Pure nickel is perhaps capable of two states of oxydation: by long exposure to an intense heat with access of air it is converted to a dark brown oxyd which is still magnetical:[c] on the other hand the colour of all its salts is green and the precipitate thrown down by decomposing them with alkali is also green, hence it may be concluded that the perfect oxyd of nickel is green, unless this colour as in the case of the green oxyds of copper be owing to a combination with water. The green oxyd of nickel by moderate ignition becomes ash-grey with a slight tinge of blue or green, and in this state, according to Klaproth[d], is composed of 66 of metal and 34 of oxygen. By further ignition it becomes of a blackish grey, and contains, according to Richter, 78 of metal and 22 of oxygen. Both the oxyds of nickel by strong ignition in close vessels even without the contact of any inflammable body are reduced to the metallic state.

Sulphuric acid, especially when heated, dissolves either nickel or its oxyd; and by evaporation to dryness, in order to drive off the superfluous acid, leaves behind a saline mass soluble in water and from which by evaporation may be obtained rhomboidal octohedrons truncated at their bases of sulphat of nickel. The colour of this salt is a bright emerald green, which by moderate ignition to drive off the water of crystallization becomes of a greenish white.

Nitric acid by the assistance of heat acts vigorously on metallic nickel or its oxyds, and forms with it a grass green solution from which are obtained by evaporation rhomboidal crystals: these on exposure to the air at first deliquate, but by long exposure to a warm atmosphere lose the greater part of their acid and crumble to a greenish white powder.

Muriatic acid scarcely acts on reguline nickel but dissolves its oxyd without difficulty; the evaporated solution deposits irregular crystals at first deliquescent and afterwards efflorescent like those of nitrated nickel.

Solutions of all the preceding salts are decomposed by the alkaline hydrosulphurets, with which they form black precipitates; but sulphuretted hydrogen has no apparent effect upon them. Prussiat of potash throws down a bright sea-green precipitate; of which, according to Bergman, 250 parts contain 100 of metallic nickel: these proportions however differ materially from those given by Klaproth, according to whom 100 grains of reguline nickel after solution in sulphuric acid give a precipitate by prussiat of potash, which after being ignited so as to become entirely attractible by the magnet weighs 300 grains.

Tincture of galls produces no precipitate or even turbidness.

The mild alkalies occasion a light apple-green precipitate of carbonated nickel in the proportion according to Bergman, when carbonated soda is employed, of 135 parts for every 100 of regulus: but according to Richter, when carbonated potash is employed, of 292 parts for every 100.

The caustic fixed alkalies also afford a precipitate amounting according to Bergman to 128 parts for every 100 of regulus.

Pure ammonia when added to saturation to any of the salts of nickel throws down a green precipitate which is again dissolved by an excess of the same alkali: the solution is now of a beautiful sky blue colour, and probably contains the acid, the ammonia, and oxyd of nickel combined together into a triple salt. The ammoniaco-nitrat of nickel, according to Thenard[e], exhibits the following properties. It deposits green crystals by evaporation; it is decomposable by sulphuretted hydrogen and the alkaline sulphurets: neither acids nor alkalies effect any change in it at the common temperature, but by ebullition with caustic potash the ammonia is driven off, nitre is formed and oxyd of nickel precipitates. It may also be decomposed by first saturating the ammonia with an acid and then adding carbonated soda.

Not only the salts of nickel but the oxyds also, and even the regulus, are soluble in ammonia, the colour of the fluid thus produced is a dark purple-blue, like the ammoniuret of copper. It is decomposable with precipitation of the metallic oxyd by either of the caustic fixed alkalies, as has been already observed in the preceding section.

None of the metals are capable of decom-

[c] Bergman, Ess. II. p. 243. 272. [d] Analyt. Ess. I. p. 432. [e] Ann. de Chem. XLII. p. 216.

posing the salts of nickel: even zinc, although assisted by an excess of muriatic acid in the solution, and a boiling temperature, has no effect on the salt when the nickel is pure: a mud-coloured precipitate indeed is not unfrequently deposited from the solution of common nickel, but this precipitate is for the most part arsenic and iron, with which nickel purified in the usual way always abounds. Hence it is that in proportion to the action of the zinc on this compound salt, the green colour of the solution becomes more and more pure and bright; and when all the arsenic capable of precipitation by this method has fallen down, no further digestion with zinc or any other metal will produce the least effect.

There are no experiments on the combination of pure nickel with sulphur or phosphorus, but as the common regulus unites without difficulty with these combustibles it is probable that the pure metal will do so likewise.

The alloys of nickel with the other metals have been but little examined.

When combined with gold in the proportion of three or four grains of the former to an ounce of the latter, neither the colour nor malleability of the mass materially differs from that of pure gold, but if the proportion of nickel amounts to 20 grains of alloy in the ounce, the result is a mixture of a brass colour, a coarse grain, and very brittle. [f]

With silver it may be combined according to Bergman, in nearly equal proportions, without impairing in any remarkable degree either the colour or ductility of the silver.

With copper it forms an alloy of less ductility than pure copper, and the magnetic quality of the nickel is diminished though by no means destroyed.

With tin it forms a white brittle compound.

By mixture with arsenic it forms a brittle and easily fusible mass, entirely incapable of being acted on by the magnet. If the proportion of arsenic in the compound is considerable, it will emit fumes of this metal by exposure to the blow-pipe, and if it be broken to pieces and roasted at a low red-heat it will be covered with a green arborescence of arsenicated oxyd of nickel: by a repetition of alternate roastings and reductions with a carbonaceous flux, the arsenic may be so far separated as that the alloy will give out no more vapours, nor produce any arborescence, after which by repeated scorification with nitre, the remaining arsenic may be almost entirely got rid of; but this method is neither so expeditious or satisfactory as that already detailed in the preceding section.

Nickel and iron seem to unite together in all proportions: the colour of the alloy approaches more to that of silver, as the nickel prevails in it; and its ductility and power of magnetism appear to be fully equal to that of pure iron. It is remarkable that all the specimens of meteoric iron that have been analysed, are natural alloys of iron and nickel, of which this latter constitutes from 1.5 to 17. *per cent.* These masses differ from pure iron in being scarcely at all oxydable by exposure to the weather, it is highly probable therefore that nickel may become a metal of vast importance if its power of protecting iron from rust be fully established.

Oxyd of nickel is soluble by fusion in various vitrescent mixtures, to which it gives different tinges of colour according to the nature of the saline ingredient made use of as a flux.

A mixture of Pure siliceous earth 80 grains,
Carbonated potash 60
Oxyd of nickel - 3
affords by fusion a hard clear violet-blue glass. [g]

Siliceous earth - 60
Calcined borax - 60
Oxyd of nickel - 3
yield a glass of a clear brown with a tinge of blue, or a hyacinthine colour. A similar effect is produced if either carbonat of soda or microcosmic salt be substituted instead of borax. With the latter of these fluxes the glass while hot is of a deep garnet-red colour.

Siliceous earth - - 60
Vitrified phosphoric acid
prepared from bones - 60
Oxyd of nickel - - - 3
produce a honey-yellow glass, but not quite transparent; this defect however is in all probability to be attributed to the phosphat of lime, which phosphoric acid so prepared almost always contains.

NIGRIN. See Titanium.

NITROGEN. See Azot.

NITRIC. Nitrous Acid. *Aqua Fortis of Commerce. Der Salpetersaure.* Germ.

This most important acid is found native in great abundance united with potash, in some parts of the East Indies, and it is also generated by the putrefaction of animal matters of various kinds, as will be explained under the article

[f] Hatchett. [g] Klapr. Analyt. Ess. I. p. 437.

Nitrat of Potash. It is alfo generated in feveral chemical proceffes, and may be produced by the direct union of its two conftituent parts, *azot*, and *oxygen*, in fufficient quantity to afford fatisfactory evidence of its chemical nature; but for the purpofes of the laboratory and manufacture, it is always prepared from nitre, by the addition of fome fubftance which has a ftronger affinity with potafh than the nitric acid has, affifted by diftillation.

The moft antient way of procuring this acid and which is ftill practifed in many countries (though now feldom in England) is by heating ftrongly a mixture of nitre and clay, or nitre and green vitriol, in earthen or iron retorts, and receiving the acid vapour in proper veffels. It was foon found that alum and fome other vitriolic falts anfwered the purpofe as well as the vitriol of iron, and laftly the great improvement was made of employing the vitriolic acid alone, which is the method now univerfally adopted in the laboratory, and chiefly in manufacture, in this country, where this acid is cheap.

The way of procuring the nitrous acid in fmall quantities, is the following: take a plain glafs retort of any fize, put into it any quantity of dry purified nitre in powder (which need not be very fine) dropping it through a paper funnel, that none may lodge in the neck of the retort, and fill it not higher than at moft two-thirds of the capacity of the body of the veffel, when the nitre lies light and uncompreffed. Then pour in (through a glafs funnel, with a ftem reaching nearly to the bottom) concentrated fulphuric acid equal to about half of the weight of the nitre, equally guarding againft any lodgement of it in the neck of the retort. Then lute on a large tubulated glafs receiver, and cement the joinings with *fat lute* (the compofition of which is defcribed under the article *Cements*). Thefe two are all the veffels abfolutely required, but the tube of the receiver muft be only loofely ftopped, or (what is a better way) it fhould dip into an empty bottle without luting the joinings. As however towards the end of the procefs much acid vapour paffes off which would be loft in the common way of proceeding, and is partially condenfible by water, one or two bottles of the Woulfe's apparatus, half filled with water, may be added to the receiver, and the abforption tubes carefully placed, fo that none of the acidulous water may be fucked back into the receiver, and mix with the ftronger acid. The retort is then to be placed in a fand-bath, and the fire applied gradually.

As foon as the nitre and fulphuric acid mix, faint orange-yellow fumes arife, but very fparingly, till by the affiftance of heat the nitre is compleatly diffolved in the acid. When this mixture begins to get hot the fumes increafe, and long wet ftreaks appear on the neck of the retort, which collect and fall down in drops in the receiver. The heat is now to be increafed till the mixture boils, and at this point of gentle ebullition the materials are to be kept, during which the drops of acid fall in quick fucceffion into the receiver, and the receiver itfelf is lined with the fame ftreaks of acid drops. Towards the middle of the diftillation, when both retort and receiver are filled with the acid vapour, the colour is only a faint orange, fo that the materials within the retort can be feen without much difficulty by looking down (for the hot fand fhould be heaped up as high as poffible, and above the level of the boiling fluid) and even if they cannot be conveniently feen the procefs will be known to go on well by the gentle uniform hiffing noife of the boiling materials, and the moderately rapid fall of condenfed drops in the receiver, which laft fhould be kept quite cold with wetted cloths on the outfide if neceffary. During all this time little, if any, gas or vapour of any kind paffes beyond the large receiver. At length the vapour in the retort becomes of a higher orange, which foon (and rather fuddenly) deepens into a very dark and nearly opake, orange-red, fo that the materials can no longer be feen; and a little afterwards thefe begin to fwell confiderably, and to rife flowly up to the neck of the retort, and if this was at firft more than half full, the hot half-fluid matter is apt to flow over into the neck, and thence into the receiver, unlefs the heat of the furnace be rapidly checked and the top of the retort cooled by removing the upper part of the fand. The diftillation is then to be continued with the heat kept up as high as poffible without boiling over, and the whole receiver now becomes darkened with red-orange fumes, which find their way on to the connected bottles, where they are chiefly condenfed in the water through which they are forced. At the fame time however a confiderable quantity of gas efcapes, which if examined, is found to be a mixture of azot with a very large proportion of oxygen. When nothing further is given out and the heat is fufficient nearly to redden the bottom of the retort, the procefs is concluded.

The products of this diftillation are:—a quantity of ftrong heavy nitrous acid, of a bright yellow colour, emitting copious orange-red

fumes, of an excessively pungent and peculiar smell, and of the specific gravity of about 1.5, or half as heavy again as water, if the nitre was thoroughly dried before it was put into the retort, and the sulphuric acid was very concentrated. The quantity of this acid is on an average about half the weight of the nitre employed. Besides this the water that receives the nitrous vapour is converted into a weak acid liquor of a blue-green colour.

The substance remaining in the retort concretes into a beautifully white spongy saline mass, consisting of sulphat of potash with a small excess of sulphuric acid. This may be dissolved out of the retort by hot water if the heat has not been so intense as to melt the glass and the salt into a kind of opake vitreous mass.

The proportions of nitre and vitriolic acid here given are two of the former to one of the latter. Even a somewhat smaller quantity of vitriolic acid will disengage all the acid of the nitre, but the remaining sulphat of potash is harder, and the heat required for distillation is greater, so that if it be a preferable object to save the retort, not less than half the weight of sulphuric acid should be employed. If this is increased to two-thirds, which is sometimes done, the distillation is still easier, but the nitric acid contains some sulphuric acid, from which indeed it is seldom free till further rectified.

To prepare only a few ounces of the acid, a sand-heat is not necessary, but the retort may be heated by a lamp.

The nitrous acid thus prepared is very strong and fuming, and the least drop stains the hands yellow almost immediately. When heated to boiling it gives out abundance of red nitrous vapour, and if kept boiling for a quarter or half an hour (which in a narrow-mouthed flask can be done without much loss of acid) it becomes when cold limpid and colourless as water, and now no longer fumes. To preserve it colourless it should be kept in a dark place, as the light gradually restores the colour.

Thus then there are two forms or species of this acid, viz. the orange-yellow fuming acid, and the pale limpid; and the former is more accurately termed in modern chemistry *nitrous* acid, and the latter *nitric*. The precise difference between the two will be presently noticed; but it may be here observed that the nitrous appears to be the nitric holding a quantity of red nitrous vapour in solution.

Common nitrous acid contains, besides nitrous vapour, a quantity of muriatic and of sulphuric acid, the former arising from a small admixture of common salt, or more commonly of muriat of potash with the nitre; and the latter from the volatilization of part of the sulphuric acid added. It is of importance often both in manufacture and in experiment, to get rid of these foreign acids, which may be done in the following way: the sulphuric acid is got rid of by redistilling the acid upon about an eighth or tenth of pure nitre in a moderate heat, by which the sulphuric acid is detained; or else nitrat of lead may be added to the mixed acid, which will cause the sulphuric to separate in the form of an insoluble sulphat, after which the clear acid may be simply decanted off, or (what is much better) should be redistilled.

To separate the muriatic acid nitrat of silver may be dropped in gradually till all the muriatic acid falls down as muriat of silver, after which the clear nitrous acid may be considered as pure, or what is better, should be redistilled.

The manufacture of this acid in the great way is now performed with equal simplicity in this country and with the same materials. The process is the following: rough nitre is first recrystallized, then the crystals are put (without pounding) into a large glass *body*, to which is added half the weight of sulphuric acid; a glass pipe is then luted to the body and made to communicate with an empty receiver, and from this by three or four more pipes with other receivers half full of water, but in this case the pipes do not dip in the water. Heat is then applied, and the strong acid condenses in the empty receiver, whilst the acid vapour unites with the water of the others, forming the common aqua fortis. To purify the strong acid from the muriatic, the following simple method is found sufficient: a small quantity of distilled water is added to several pounds of the acid, which causes a great production of heat and a sudden gust of nitrous fumes, and in these fumes all the muriatic acid escapes, being more volatile than the nitric acid. By subsequent boiling the rest of the nitrous vapour is got rid of, and the acid that remains is a nearly pure nitric acid, of about 1.5 specific gravity. The residuary sulphat of potash is mostly sold to the alum-makers in Scotland.

The furnace and apparatus of an aqua-fortis distiller consist chiefly of a long iron trough filled with sand, in which the retorts are buried in two rows, standing back to back, and under which is a long brick furnace to heat the sand. Each retort has its own receiver. Sometimes instead of glass retorts, very thick iron pots are substituted with advantage. These

will last a very considerable time before they are so much worn as to be unserviceable.

Nitrous acid is also prepared in the large way in some countries by distilling nitre and clay, sometimes nitre and martial vitriol. The apparatus for both is the same, namely, large earthen pear-shaped pots, in which the materials are heated, and earthen globes for receivers. The pots are ranged in a long furnace in a double row, as already described. When clay is the material used a harsh vitriolic clay is selected, which is first well dried in a small oven, then beaten to rough powder and sifted. About five parts of nitre are taken to twelve of the clay, and when well mixed, the mass is wetted either with water or with the weakest acidulous phlegm of former distillations. The mixture is then put into the pots, and the fire is kindled and kept up with those precautions which practice alone can teach, and the distillation continued till all the acid has come over, and the pots are nearly red hot. The acid procured in this way is generally pretty good, but must undoubtedly be much weaker than when made with sulphuric acid and nitre, since it is not uncommon to obtain nearly as much nitrous acid as the weight of nitre employed. Indeed it is obvious that it must contain all the moisture originally left in the clay, as well as that employed in the mixture of the clay and nitre. The affinity that acts here in the production of the acid, must be that of the clay for the alkali of the nitre, when strongly heated. Besides this the clays used are considerably vitriolic, which also assists in the expulsion of the nitrous acid. The residue in the retort is a hard half-fused earthy mass, now turned to a deep red (owing to the compleat oxydation of the iron of the clay) and consisting of all the earths of the clay, the alkali of the nitre, and a little sulphat of potash, which last may be separated by boiling water. This residue is called *cement earth of aqua fortis*, and is only used as a red earth in staining tiles, bricks, &c.

The process for making aqua fortis by martial vitriol (which is a very good method and much used on the continent) * is very simple. The vitriol is first calcined till it falls into a white powder, by which it loses nearly half its weight of mere water, but little or none of its acid. The calcined vitriol is then mixed with about its own weight of pure nitre, and the mixture is put in some works, into earthen, in others in iron pots, to which glass receivers are well luted (but with a small vent-hole, for the uncondensible vapour to escape when opened) and the fire is gradually raised to redness during which the acid distills over. In this as in other distillations of this acid a fat lute made of clay and linseed oil is generally employed. The acid procured in this method is more ruddy and fuming than in any other, so as to be almost brown and opake, and in the process the receiver is often found starred with crystalline rays, which again melt down. These are probably sulphuric acid driven off by the violence of the heat and saturated with nitrous vapour, which (as will be elsewhere mentioned) renders this acid crystallizable. The residue of this distillation is a mixture of sulphat of potash and red oxyd of iron, which is easily got out unless the nitre was mixed with common salt, in which case it adheres very closely to the vessel. The sulphat of potash is got out by lixivation with hot water, and the insoluble residue is a perfect oxyd of iron of a blood-red colour, called *colcothar*, and when well washed and sifted is much used by the looking-glass makers to polish their mirrors.

Other substances are occasionally used to disengage the nitrous acid from nitre, where they can be procured cheap. Sulphat of magnesia is very useful for this purpose, and in the neighbourhood of salt-works it may be sometimes obtained economically in sufficient quantity. In this case there appears to be first a double decomposition of the ingredients, by which sulphat of potash and nitrat of magnesia are produced, and then the heat drives the nitric acid off, so that the residue contains both sulphat of potash and uncombined magnesia. It is from very few other substances however that the nitric acid can be expelled by heat undecomposed, for when the nitrated alkalies and most other nitrated earths are heated, the acid is decomposed almost at first, and the products are, not nitric acid, but the elements of this acid disunited. Hence it is that nitre alone cannot be made to yield its acid by heat.

The distilling vessels are made either of glass, or earth, or iron. The former is undoubtedly the best material, but is expensive and liable to accidents. Iron retorts when made very thick at bottom last a considerable time, but the acid gradually acts upon them and produces much red nitrous vapour, which causes the acid to be always excessively fuming and high-coloured. In some parts of Wirtemberg it appears that they

* Encycl. Arts & Metiers. Art. *Eau Forte*.

have a way of lining the iron pots with an enamel glazing, which muſt unite all the advantages of iron and glaſs.

* * * *

Nitric acid with its varieties and combinations has been the ſubject of more laborious, profound, and various chemical reſearch than perhaps any other ſubſtance that has ever occupied the chemiſt: and it is well entitled to this attention on account of the readineſs with which it is decompoſed, and the great aſſiſtance which as a chemical reagent it affords in the analyſis of almoſt every other ſubſtance in nature.

From the admirable reſearches of Scheele, Cavendiſh, Prieſtley, Lavoiſier, Berthollet, Davy and many others, we have now acquired a tolerably accurate idea of the nature and combinations of this acid, though ſome important points ſtill remain uncertain.

The appearance and colour of this acid vary conſiderably: in one ſtate it is perfectly limpid and colourleſs, and when poured out ſends forth whitiſh pungent fumes: it is then properly called *Nitric* acid. In another ſtate it is yellow orange or ſometimes of a dark red, emitting copious red fumes, when it is termed in modern nomenclature *Nitrous acid*.

Lavoiſier was of opinion that the difference between theſe two acids conſiſted in the degree of oxygenation, the former being the moſt, the latter the leaſt oxygenated. This diſtinction however, though in one ſenſe it expreſſes the fact, is not perfectly accurate, ſince it will be ſeen by numerous experiments to be preſently related, that the nitric acid becomes converted into the nitrous ſimply by abſorption of nitrous gas without any obvious difference in the degree of oxygenation of the nitric acid itſelf, and conſequently when either acid is ſaturated with an alkali the reſulting ſalt is the ſame in both, and not a more oxygenated ſalt with the nitric, and a leſs oxygenated with the nitrous, as would happen were the acid itſelf different in each. Therefore though the actual quantity of oxygen is greater in a given weight of nitric acid than in the ſame weight of nitrous acid, and though they are both compoſed of azot and oxygen, there appears to be only one ſtate of oxygenation of this acid, and the nitrous gas which makes the difference between the nitrous and nitric acids muſt be here conſidered as doing little more than diluting the acid, and thus diminiſhing the actual quantity of it in a given weight.

Pure colourleſs nitric acid is invariable in its compoſition as far as has hitherto been found, and no other varieties of it are produced in diſtillation than what ariſes from the quantity of water with which it is diluted, and with which it will mix in every proportion.

Nitrous acid on the other hand exiſts in an indefinite number of varieties according to the quantity of nitrous gas which it contains, which laſt again is regulated both by the quantity of water preſent, and by the temperature. There is however a point of ſaturation of nitric acid with nitrous gas, at which it aſſumes a blue-green colour. With leſs quantities of nitrous gas the colour is green, olive, red, and yellow. The degree of dilution with water however much influences the colour of the acid.

There is another form of acid which alſo requires particular notice, and it is that which Dr. Prieſtley in his moſt admirable reſearches on this acid called *Nitrous vapour*. It is nitrous acid in the form of red vapour, and conſiſts of nitrous gas holding nitric acid in ſolution. It is produced in ſeveral methods; for example, if to nitrous gas be added oxygen gas, a red cloud is formed, which, if the gaſſes be confined over water, is readily abſorbed, but if no water be preſent it remains as a permanent gas, and this is nitrous vapour. It is alſo expelled from the fuming nitrous acid by heat, and it is produced during the ſolution of biſmuth, and ſome other of the metals in nitric acid, where the action is very violent, the nitrous gas always generated in theſe ſolutions, here diſſolving and carrying up a portion of the acid.

Nitrous gas therefore when in large quantity has a ſtrong tendency to volatiliſe the acid, and this is more powerful in proportion to its concentration, or inverſely as the water which it contains. The proportions of nitrous gas and nitric acid in nitrous vapour vary conſiderably.

There are four diſtinct ſubſtances concerned in the ſubject of nitric acid, namely: *Nitrous gas*, (whoſe properties have been partly deſcribed under the article *Eudiometry*, and will be further noticed in their place,) *Nitrous vapour*, or a gaſeous combination of nitrous gas and nitric acid, *Nitrous acid*, compoſed of nitric acid, water, and nitrous gas in varying proportions, and *Nitric acid*, or the pure ſaturated form of azot and oxygen, rendered liquid by union with water. Another combination of theſe elements, *Nitrous oxyd* or *gaſeous oxyd of azot*, (*dephlogiſticated nitrous air* of Prieſtley, will be ſeparately deſcribed, and its properties need not here be conſidered.

We ſhall firſt mention ſome circumſtances that occur during the diſtillation of nitric acid that affect the nature of the product. If the acid that comes over be examined at different periods of the diſtillation, the firſt portion will have the greateſt ſpecific gravity and alſo the leaſt colour. Dr. Prieſtley[b] has an experiment to this purpoſe. On receiving the acid at four times, the firſt produce was very pale, and heavier than the ſucceeding portions, effervеſced violently with water, emitting red fumes. The ſecond part of the produce was ſtill paler, and alſo effervеſced with water. The third part was brown, and mixed with water quietly: the fourth was of a deep orange colour. Prouſt has given the following experiments on this ſubject. A pure nitric acid[c] was prepared by nitre and ſulphuric acid which gave no precipitate with nitrat of barytes, and therefore contained no ſulphuric acid. This was boiled to expell ſome of the ſuperfluous nitrous gas, after which it remained yellow, and of the ſpecific gravity of 1.52. The ſame acid being again diſtilled, the firſt product was 1.51 ſp. g. and leſs yellow: the ſecond product which was ſtill paler was alſo 1.51, but the remainder in the retort which was quite colourleſs, was only 1.47. It may be obſerved that the ſtronger the acid is the leſs heat it requires to be volatilized. Mr. Perceval[d] found on diſtilling two pounds of nitre with one of oil of vitriol and dividing the product into three equal parts, that the firſt portion was 1.494 ſp. gr. the ſecond 1.485, and the third 1.442.

From theſe experiments it is ſhewn to be impoſſible to concentrate the nitric acid by diſtillation, ſo that when the moſt concentrated acid is required, very dry nitre and ſtrong ſulphuric acid muſt be uſed, and the firſt product ſet apart. Mr. Kirwan[e] found that the ſtrongeſt acid he could procure was 1.5543 ſp. gr. at 60° It was yellowiſh red, and exceſſively fuming and volatile. This laſt circumſtance is owing to the ſmall quantity of water contained in the materials before diſtillation, as Dr. Prieſtley had alſo remarked, for the quantity of nitrous gas which nitric acid is capable of diſſolving is inverſely in proportion to the water it contains. Hence it is that even a concentrated pale acid (which however ſtill holds much nitrous gas in ſolution) will give out copious red fumes of nitrous vapour on dilution with water.

The effects of heat on nitric acid are curious and intereſting. Dr. Prieſtley was the firſt that examined this ſubject with accuracy; many of his experiments deſerve particular mention. In moſt of them the acid was incloſed in glaſs tubes hermetically ſealed by melting the end of the glaſs by which all action of external ſubſtances was prevented except heat and light which could permeate the glaſs. Some ſtrong nitric acid of a pale yellow was put into a glaſs tube four feet long and one third of an inch in diameter, the ſpace occupied by the acid being about two inches of the tube, and the open end through which it was introduced was cloſed hermetically. The tube thus prepared was held in the hand at the empty end, and the other preſented to a common fire. The firſt effect was the acid aſſuming an orange colour throughout, after which an orange-coloured vapour appeared above the ſurface of the acid and gradually aſcended higher in the tube, at the ſame time that the acid grew paler and at laſt was left again colourleſs. The red vapour roſe higher and higher in the tube as the heat was continued, leaving a conſiderable ſpace between it and the acid, ſometimes as much as ten or twelve inches of the tube, quite tranſparent. On continuing the heat however the quantity of vapour increaſed and the colour deepened. It was then removed from the fire, when the red vapour preſently deſcended to the ſurface of the colourleſs acid, and entering into it communicated the orange colour. The acid however did not ſeem to be more coloured than at firſt by this proceſs, but on repeating it with the ſame tube for many times, and boiling it for a conſiderable time the vapour changed from orange to green, and the acid remained permanently of an orange-red. The effect of heat upon the coloured acid is quite the reverſe of that on the nitrous vapour, for when the vapour is heated its colour always was found to deepen to a dark orange-red, whereas the coloured acid becomes pale and limpid. If the moſt coloured acid be boiled in *open* veſſels ſo as to allow the eſcape of the nitrous vapour, it remains pale after it is cold, but in cloſed tubes (as above related) the vapour generated by the heat and confined over the ſurface of the acid, is (in part at leaſt) again abſorbed on cooling, and imparts its own orange colour.

That the effect of heat is actually to expell the vapour from the acid, is proved from the circumſtance that when a part of the tube was ſoftened by heat, the preſſure of the vapour within burſt through the glaſs at that part. The degree in which the acid is compreſſed by the nitrous vapour, or (which is the ſame) the

[b] Experiments on Air, vol. i. [c] Journ. de Phyſ. Tom. 49, p. 59. [d] Royal Iriſh Tranſ. vol iv. [e] Ibid. p. 13.

degree of denſity of the vapour, much affects the colouring of the acid, ſo that other things being the ſame, the acid will aſſume a higher colour when heated in a ſhort tube than in a long one where the vapour can expand.

The contact of air was not found at all neceſſary to the colouring of nitric acid, for on confining ſeparate portions of acid in tubes with different ſpecies of air and in vacuo, and applying an equal degree of heat to all, they all aſſumed nearly the ſame ſhade of colour in a given time.

The ſmalleſt quantity of combuſtible (or phlogiſtic) matter will almoſt immediately render pale nitric acid high coloured when added to it, and the ſame change takes place in a ſhort time even when the matter is only contiguous to it, as for example when the acid is kept in a phial ſtopped with a cork.

Fuming nitrous acid is made colourleſs by ſimple expoſure to the air, but this ſeems to be effected ſolely by the great dilution which it gradually undergoes from the water which it abſorbs from the atmoſphere. Thus Dr. Prieſtley found on expoſing a glaſs tumbler containing ſome of the acid to this open air, that in a day or two it became colourleſs, and for ſeveral months it gained weight notwithſtanding the loſs which it muſt have undergone by evaporation, till it had acquired double its original weight, and of courſe was proportionally dilute.

Light alſo has a ſimilar effect with heat in colouring pale nitrous acid, which, as the ſame excellent obſerver has remarked, takes place in a few days, but it appears to act only on the vapour of the acid, for even the paleſt acid when concentrated is conſtantly ſending forth a vapour which is at firſt colourleſs, and this vapour when coloured by the light ſeems to react on the acid and to effect a ſimilar change. Light however is not neceſſary to aſſiſt the action of heat ſince the ſame change was found by heating the acid in opake veſſels as in tranſparent ones. To prove that the colorific action of light was exerted only on the vapour of the acid, Dr. P. made a quantity of colourleſs acid by boiling the common yellow acid haſtily, and letting it cool in the dark, and put different portions of it in phials, ſome of them quite full, others only half full and with different ſpecies of air incumbent upon them, and expoſed them all to the ſun's rays for a few days. After this time the acid in all the phials that were only half full was conſiderably coloured, but in the full bottles it remained as colourleſs as water. The ſame effect was produced on the vapour when a vacuum was made over the acid as ſoon as introduced. Alſo on throwing the ſtrong light and heat of a lens on the upper part of a phial half full of acid, the vapour became ſpeedily coloured, and this being imbibed by the acid gradually tinged it, the colour ſpreading from above downwards.

Whenever pale nitric acid is made to yield a quantity of red nitrous vapour there is at the ſame time a production of oxygen gas, and alſo as appears from Dr. Prieſtley's experiments, a quantity of azotic gas.

He found on filling a tube with the pale acid, boiling it within the tube and cloſing it hermetically when boiling, (in which way almoſt every particle of atmoſpheric air is excluded by the boiling vapour) that after the acid has been coloured by heat and red vapour formed, a quantity of air ruſhed out of the tube when opened, which was found to conſiſt of a large proportion of oxygen and ſome azotic gas. Thus it appears that oxygen gas and nitrous vapour can exiſt in the ſame place and in a ſtate of conſiderable condenſation, without mutual decompoſition.

The action of heat on nitric acid therefore appears to be the following: ſuppoſing the acid to contain no ſeparable portion of nitrous gas in ſolution, the heat appears firſt to decompoſe part of the acid into nitrous gas and oxygen, and theſe being expelled as ſoon as formed, carry up in ſolution a certain portion of undecompounded acid, and the three together form *nitrous vapour*. The oxygen however ſeems not to be an eſſential conſtituent of the vapour and perhaps is only mechanically mingled with it. If the acid is cloſely confined in a veſſel which it does not fill, the vapour remains unchanged in the empty ſpace above the acid, and when the heat is withdrawn, a portion of it (more or leſs according to the denſity and elaſticity) is again abſorbed by the acid and renders it coloured. A part at leaſt of the oxygen gas remains in the gaſeous ſtate unaltered, but it is by no means improbable that as ſoon as the heat is removed, another part of the oxygen may again combine with the nitrous gas which it had quitted and return into the body of acid.

Where pale nitric acid is encloſed in veſſels which it entirely fills it is probable that no continuance of heat could render it coloured, for as the colouring is owing to its diſſolving nitrous gas, and as this gas cannot be formed without the previous decompoſition of a portion

of acid and production of oxygen gas, where no room is afforded for the eſcape of oxygen in its proper gaſeous form, its production muſt be prevented. But on the other hand the narrower the vacant confined ſpace is, above the acid, the more ſpeedily will it become ſaturated with nitrous gas, owing to the conſtantly accumulating preſſure of the oxygen gas above it.

The effect of heat on nitric acid already ſaturated with nitrous gas, or in the coloured fuming ſtate, and *unconfined*, is ſimply to expell the nitrous gas, and a portion of the acid in the form of nitrous vopour, and thus to leave the acid pure and colourleſs.

The more concentrated the acid is the greater is the quantity of nitrous gas which it will abſorb, and at the ſame time the eaſier will it again give out the gas when heated.

It may appear contradictory to experience that nitrous gas, which in its natural ſtate is ſo greedy of oxygen and unites with it ſo readily, ſhould appear to mix with it in combination with vaporized nitric acid without contracting any union with it. It is by no means improbable however that this is only during the application of heat, which is conſtantly obſerved to counteract the chemical union of gaſeous bodies, and beſides, the preſence of the acid vapour may operate in preventing this union, for it does not neceſſarily follow that the affinities of nitrous gas ſaturated with acid vapour ſhould be the ſame as ſimple nitrous gas.

The union of nitrous gas with nitric acid both diminiſhes its ſpecific gravity and gives it a prodigious tendency to volatilization, and as will appear from ſome experiments which will be preſently mentioned, this acid may be totally diſſipated in red nitrous fumes when the quantity of nitrous gas or vapour is exceſſive.

The compoſition of nitrous vapour is certainly various, and it may exiſt with an exceſs either of oxygen or of azot according to the way in which it is procured, and by this Berthollet explains ſeveral apparent contradictions in its phenomena.

The analyſis of nitrous vapour is extremely difficult, owing to the impoſſibility of confining it unaltered in jars by any known fluid, as it acts powerfully on almoſt every fluid in nature. Dr. Prieſtley made many attempts to procure it in quantities and tolerably uniform in its compoſition. He found it produced readily by the rapid ſolution of biſmuth in nitric acid, but the method on the whole the moſt convenient was to diſſolve lead in dilute nitric acid, and evaporate the ſolution to compleat dryneſs. This left a white nitrat of lead, which when put into a ſmall glaſs tube or retort and heated ſtrongly gave a large quantity of red nitrous vapour in conſiderable purity. This ſpecies of nitrous vapour however ſeems to differ from that produced by the ſuper-ſaturation of nitrous gas with oxygen confined by mercury, and from that produced by heat from nitric acid, for this from the nitrat of lead abſorbs oxygen from the air in the ſame way as common nitrous gas only not ſo rapidly. It is with this nitrous vapour that Dr. Prieſtley made many experiments on its abſorption by different bodies, ſome of which are as follows:

Water impregnated with this vapour was increaſed one third in bulk, and in this ſtate when left at reſt was conſtantly again exhaling the vapour with great force ſo that it could with difficulty be kept in cloſe-ſtopped phials. The colour was bluiſh green. On pouring a little into a glaſs and blowing away from the ſurface the red vapour iſſuing out, the colour of the liquor gradually changed to pale yellow like common nitrous acid, and it was in every reſpect ſimilar to this acid. The acid made in this way is alſo purer than the common ſpirit of nitre, as it contains no admixture of muriatic acid.

Oils abſorb this vapour readily and in general are ſtiffened and coagulated, as will be further mentioned under the article *Oil*.

Sulphuric acid abſorbs nitrous vapour. On putting a little of the acid into a phial full of the vapour and ſhaking it for a time, the red colour of the air diſappeared and a vacuum was formed above the acid, which laſt became of a light blue colour exhaling a white vapour. On putting ſome of this acid into a glaſs and gently pouring water on it no change was obſerved at firſt, but on ſtirring the mixture great heat was excited, and a vaſt quantity of red vapour was expelled with vehemence. The acid after this ſeemed to have loſt all that it had before abſorbed and to be merely ſulphuric acid diluted with water. When concentrated acid is fully ſaturated with nitrous vapour and ſuffered to remain at reſt for a time it cryſtallizes, as will be further mentioned under the article *Sulphuric acid*.

The muriatic acid alſo abſorbs the nitrous vapour and in conſequence aſſumes a deep orange colour, but without much increaſe of bulk, and is converted into a very powerful *nitro-muriatic acid* or aqua regia.

Having thus given a ſhort abſtract of ſome of Dr. Prieſtley's moſt important experiments

on nitrous acid, we proceed to mention others by which it has been attempted to ascertain the exact proportion of the constituent parts of nitric acid and its several modifications.

Chemistry is indebted to Mr. Cavendish for the important discovery of the true nature of nitric acid; this eminent philosopher having composed the acid by passing the electric spark for a vast number of times through a mixture of azotic and oxygen gasses, and thus demonstrated that azot is its radical or basis.[e]

The apparatus employed in these interesting experiments consisted of a glass tube bent in the form of the letter V, which after being filled with quicksilver, was inverted into two glasses of the same fluid. The air to be tried was then introduced into one of the legs of the tube, and in the other were thrown up test liquors, or other fluids as required. A communication was then made with a powerful electric machine, so as to take sparks successively through the air in the tube. Common air alone was first tried (which consists of about 77 *per cent.* of azot and 23 of oxygen) and litmus liquor was introduced in contact with it up the other leg of the tube. On passing the spark through it repeatedly the litmus liquor acquired a red colour, and the air was diminished. When lime-water was introduced instead of the litmus, not the least turbidness was perceived, though the air went on diminishing to two-thirds of its original bulk. A mixture of azotic and oxygen gasses was then tried, and the lime-water as before remained clear, but on adding ammonia a brown sediment appeared. This consisted of carbonat of lime mixed with a little mercury, which the electric spark had oxydated, and hence both the lime and the mercury must have been dissolved in the water of the lime-water, by some acid, which acid was afterwards proved to be the nitric.

Mr. Cavendish afterwards found that the production of nitric acid from these two airs, was much hastened by electrizing them in contact with a substance for which the acid when formed has a great affinity, and accordingly soap-lees or caustic potash was used.

One leg of the tube being filled with a mixture of azot and oxygen, and the other with the alkaline solution, sparks were taken through the air for a great number of times, after which the alkaline liquor was found compleatly saturated with acid, and on being evaporated to dryness a small quantity of a salt was left, which was evidently nitre. In several experiments however when the electrization was continued so long that the acid produced was more than sufficient to saturate the alkali, the excess of acid dissolved a little of the mercury by which it was confined, and nitrat of mercury was also found mixed with the nitrat of potash. The particular tests by which the presence of nitrat of potash and nitrat of mercury were detected need not be here related; it is sufficient to observe that they were perfectly satisfactory.

From these most valuable and fundamental experiments it is proved, that nitric acid consists of azot of oxygen in certain proportions, and that the electric spark is capable of making them unite in that form and proportion which is necessary to constitute this acid, whatever be the actual proportions of these gasses in contact with the electric spark. Hence too we find that nitric acid is always generated whenever the electric spark is taken in the open air.

The process as given by Mr. Cavendish is extremely laborious, and requires great perseverance, as even with a powerful machine, and continuing the electrization for several days, only a very few grains of nitre are produced in the potash solution.

Mr. Henry[f] has given the following very accurate directions for performing this experiment: let a straight tube prepared for electrical purposes, be filled with and inverted over mercury. Pass into it a portion of common air, or, in preference, a mixture of azotic gas with twice its weight of oxygen. Let an iron wire lengthened out with one of platina, be introduced within the tube, so that only the latter metal may be in contact with the mixed gasses, and let the end of this wire be distant ¼ of an inch from the extremity of the upper one. Then pass a series of electric shocks through the gasses for several hours. The mixture will gradually lessen in bulk, will redden litmus introduced within it, will give the smell of nitrous acid, and will neutralize a few drops of potash, and produce nitre.

On account however of the difficulty of procuring any tolerable quantity of nitric acid in this way, the proportion of its ingredients cannot be inferred with much accuracy. Mr. Cavendish did not find any very satisfactory agreement in the actual quantities of the gasses absorbed in the different experiments, but on the whole it appears from them, that somewhat more than twice as much pure oxygen as azot constitutes nitric acid.

[e] Phil. Trans. Vol. lxxv. and lxxviii.

[f] Epitome of Chem. 4th Edit.

A very interesting fact relating to the production of nitrous acid from ammonia and a metallic oxyd was discovered in 1789 by the Rev. Isaac Milner.[a] The production of ammonia from nitrous acid and iron in some circumstances, had been before discovered by Dr. Priestley, which led Mr. M. to endeavour to reverse the experiment, and produce nitrous acid by the decomposition of ammonia by means of a metallic oxyd, when in the act of giving out oxygen. It was made in the following manner: the middle part of a clean gun-barrel was filled with black oxyd of manganese, rammed in gently and in coarse powder, so as to admit the passage of vapour through. The barrel was then made red-hot in the middle, and at one end was luted a small retort filled with caustic ammonia, which was made to boil by a lamp heat, and the ammoniacal vapour was thus forced through the red-hot manganese. Nitrous fumes soon began to appear at the other and open end of the gun-barrel, and a considerable quantity of air was collected which was clearly nitrous. Owing to the impossibility of exactly adapting the quantity of alkaline vapour to the oxygen which the manganese is giving out, there will be always found a great variety in the gaseous products, but nitrous gas is always given out and generally with the usual appearance and smell of the red nitrous vapour when it comes in contact with the air. Sometimes however when much ammonia is passing through the barrel and but little oxygen giving out, the product is a mixture of nitrous gas with ammonia, and on coming in contact with air the nitrous gas becomes for an instant red by changing into nitrous vapour, after which it unites chemically with the alkali, and the receiver is filled with white clouds of nitrated ammonia.

In this interesting experiment the ammonia is resolved into its elements, azot, and hydrogen, and the azot uniting with the oxygen of the manganese forms nitrous gas or nitrous vapour, according to the degree of saturation.

Nitric acid when in vapour is decomposed by a red heat, and the products are very pure oxygen gas, nitrous gas, or nitrous vapour, or if the decomposition be compleat, azotic gas. To give the vapour of boiling nitric acid a red heat, Dr. Priestley adopted his own ingenious method, of heating red-hot the middle of a glazed earthen tube, loosely filled also with fragments of hard pottery to increase the red-hot surface, and passing through it the boiling vapour expelled from a quantity of pale nitric acid heated by a lamp at the other end. In this way the products were a large quantity of the purest oxygen gas and abundance of nitrous gas, nitrous vapour, and some undecomposed acid.

Many other series of experiments have been made by skilful chemists, to ascertain the exact proportion of the constituent parts in nitric acid and its varieties. As our limits will not allow us to relate them all, we shall conclude this part of the subject with those of Mr. Davy,[b] which yield to none in accuracy, and are generally allowed by chemists to form as near approximations to truth, as can be expected in this peculiarly difficult and delicate part of chemical analysis.

The methods used to estimate separately the constituents of nitric acid, have been the following: *1st.* By the decomposition of pure nitre either by heat alone or by charcoal or some other combustible. But this process is attended with almost insuperable difficulties; a great variety of products are formed in this way, all of which would require a separate analysis with an infinite number of precautions and necessary corrections, and a portion of the acid is volatilized without decomposition. *2dly.* By the immediate combination of oxygen and azot, in Mr. Cavendish's method. But this though simpler than the former, is nearly impracticable on account of the extreme laboriousness of the process and the very small quantity of acid product: and accordingly we find no sufficiently satisfactory agreement even in the careful experiments of the discoverer. *3dly.* By the combination of nitrous gas and oxygen, as in the common eudiometrical trials, and the subsequent absorption of the generated acid by a given quantity of water. But Mr. Davy found that the residuary azot, which is always mixed with the purest nitrous gas and oxygen, in whatever way obtained, carries with it a variable quantity of nitrous acid vapour, of different composition from the acid absorbed, and thus renders the experiment inaccurate. The method Mr. Davy adopted was, to exhaust a glass globe of its common air, then to throw in a given quantity of nitrous gas, and after it oxygen gas somewhat more than sufficient to saturate it, then to add water to absorb the nitric acid formed (and which before the addition of the water remained in the state of permanent vapour); then to allow common air to enter to take the place of the condensed nitrous acid vapour; then to add ammonia to

[a] Phil. Trans. Vol. 79. [b] Researches.

absorb the acid which the water would not condense, and thus by subsequent calculations founded on the specific gravity of the gasses used and the acid product, to find a *standard acid*, the composition of which should be accurately known. It will not be uninteresting to give in a general way the particulars of the standard experiment, to shew more clearly the manner of effecting it, and also the numerous data and calculations required to come at the result.

The first step was to ascertain by actual experiment the specific gravity of all the gasses to be employed. The *nitrous gas* was procured from a solution of mercury in nitrous acid, and its purity tried by agitating a small portion with a solution of sulphat of iron, by which the whole of the nitrous gas was absorbed, and nearly all the azot mixed with it was left: 100 cubic inches of pure nitrous gas were found to weigh 34.3 grains at 56° therm. and 30.9 bar. The *oxygen gas* was obtained from oxyd of manganese by sulphuric acid, and its purity tried by nitrous gas and sulphat of iron. Hence 100 cubic inches of pure oxygen gas at the above heat and pressure, were found to weigh 35.09 grains. The *azotic gas* was obtained from the residue of common air after the oxygen had been absorbed, and 100 cubic inches weighed 30.43 grains. Lastly the *atmospherical air* of the laboratory was analysed, and 100 cubic inches of it weighed 31.9 grains. The experiment was then conducted in the following manner.

A glass balloon with a stop-cock, of the capacity of 148 cubic inches, was taken for the purpose of combining the gasses. The whole weight when full of common air was 2066.5 grs. It was then partially exhausted by the air pump, till it lost 32 grains, so that 15 grains of air remained in it. After this 82 cubic inches of nitrous gas were thrown in, which made the outside of the balloon sensibly hot, and produced an orange coloured vapour within. Some common air then entered accidentally, the weight of which was noted. Then 70 cubic inches of oxygen gas were introduced, whereby the heat was increased and the colour changed to a very dark orange. To absorb the nitrous acid formed, 41 grains of water were introduced, by which the dark orange colour rapidly diminished and soon disappeared. To ascertain the quantity of vapour condensed by the water, the vacuum produced thereby was filled with common air, of which 51 cubic inches, or 16.5 grains, rushed in. The acid liquor in the globe (produced by the water and the acid vapour which it had condensed) was then examined, and was found slightly green, and of 1.301 specific gravity.

To find whether any unabsorbed nitric acid remained in the vessel, 13 grains of liquid ammonia were added, which produced a white cloud with the remaining acid vapour, after which all the residual gasses were displaced by common air. The balloon was weighed after every process. By calculations from the above experiment it was found that 57 cubic inches of acid gas were formed, weighing 40.56 grains; this was composed of 27.6 grains, or 80.5 cubic inches of azot, and 12.96 grains, or 36.9 cubic inches of oxygen, which, condensed by 41 grains of water, produced an acid of 1.301 specific gravity. Therefore, reducing the whole to centenary proportion, 100 cubic inches of *aeriform nitrous acid* (or nitrous gas saturated with oxygen and excluded from the contact of water or any other substance that could act upon or absorb it) at temperature 55° and 30.1 bar. weigh 75.17 grains.

Secondly: 100 grs. of this gasseous acid are composed of 68.06 nitrous gas and 31.94 oxygen; or (assuming that 100 parts of nitrous gas consist of 55.95 oxygen and 44.05 azot, as will be mentioned under the article *nitrous gas*) of about 30 azot and 70 oxygen.

Thirdly, 100 grs. of a pale green solution of this acid in water, of 1.301 sp. gr. are composed of 50.62 water and 49.38 acid.

A standard acid of known composition was thus obtained, but it was dilute, and many of the subsequent experiments were to be performed on the concentrated acid. But as there is no known method of concentrating [illegible] acid without partial decomposition, Mr. D. was obliged to make a dilute acid composed of a given quantity of the strongest yellow acid of 1.5 sp. gr. and water, which should as nearly as possible resemble in weight and colour the standard acid produced by the union of the gasses. This after many trials in a small graduated glass tube was found to be effected by combining at 40° therm. 90 grs. of the yellow acid of 1.5. sp. gr. with 77.5 grs. of water, and hence the composition of the above yellow acid was inferred to be, in 100 grs. 91.9 of *true* nitrous acid (or such as exists in the aeriform state saturated with oxygen) and 8.1 grs. of water, supposing the relative quantities of oxygen and azot to be the same in each.

But on the other hand the acid of 1.5 here used was the *yellow* or *nitrous* acid, and it became a further question to ascertain the precise

difference between this and the *pale nitric* acid of the same specific gravity. This was attempted by heating the yellow acid, which, as already mentioned in this article, drives the superabundant nitrous gas out of the acid and leaves it pale and colourless. One hundred and fifty grains of the yellow acid of 1.5. sp. gr. were put in a small matrass with a curved tube, and on the first application of heat the colour changed to a deep red. In a short time a red vapour appeared in the tube and was conveyed into a noted weight of water by which it was absorbed, giving the water a bright green colour. By continuing the heat the acid became pale, and when cold was weighed and had lost 15 grs. but its specific gravity was *lessened* to 1.491 and 2¼ cubic inches of nitrous gas were collected that had passed through the water unabsorbed. This experiment however was found inconclusive, since the nitrous gas expelled from the yellow acid in the process of its conversion to the pale, had carried off with it in the form of nitrous vapour a portion of acid dissolved in the gas. It was necessary therefore to resort to the synthetical method, or that of impregnating a given portion of the pale acid with nitrous gas. In a proper apparatus 90 grs. of the pale acid of 1.504 were introduced and nitrous gas was thrown up, whereby the acid became warm and the colour changed first to a pale straw, and as more of the gas was absorbed, to a bright yellow. By this 8 cubic inches of nitrous gas were absorbed, the acid gained 3 grs. in weight, and the specific gravity was diminished to 1.5. These data were assumed as the means of comparing the relative composition of the pale and the yellow acid, both of 1.5 sp. gr. The power of absorbing nitrous gas and the change produced thereby on the acid was carried still further, and the same yellow acid of 1.5 when returned into the apparatus became gradually, as the gas passed into it, dark orange, light olive, dark olive, then of a muddy green, and lastly a blue green. This was the utmost change that the acid could assume, after which the nitrous acid appeared to pass through the acid unaltered. The increase of weight was only 1 grain and the specific gravity of the acid was now only 1.474. On account however of the large quantity of nitrous gas which passed through unabsorbed, and the acid which was volatilized along with it, no accurate deductions could be drawn from the experiment, except the great and successive changes of colour and the great diminution of specific gravity. A quantity of this blue green acid saturated with nitrous gas was then put into a small glass apparatus and slowly heated, when the nitrous gas was again given out with rapidity and the acid passed back through the successive colours of green, olive, red, and orange, to a perfectly colourless state, and when cold its specific gravity was then *increased* from 1.474 to 1.502. The quantity of blue green acid used was 94.25 grs. and it had lost 31 grs. in passing to the colourless state. The inferences from these and many other experiments (which from their complicated nature, and the numerous corrections required, on account of the solubility of nitric acid in nitrous gas are only given as approximations to the truth) and the relative proportion of ingredients in the different varieties are given by Mr. Davy in the following tabular form.

100 parts	Sp. Gr.		Nitric Acid.	Water.	Nitrous Gas.
Pale nitric acid - - -	1.504	contain of	91.55	8.45	0.
Yellow nitrous - - -	1.502		90.5	8.3	1.2
Bright yellow - - - -	1.5		88.94	8.1	2.96
Dark orange - - - -	1.480		86.84	7.6	5.56
Light olive - - - - -	1.479		86.	7.55	6.45
Dark olive - - - - -	1.478		85.4	7.5	7.1
Bright green - - - -	1.476		84.8	7.44	7.76
Blue green - - - - -	1.475		84.6	7.4	8.

In a second table the respective quantities of oxygen and azot in different varieties of the acids are thus given, but it must be observed that the oxygen specified is only that which belongs to the acid, and not to the water with which it is necessarily combined to give it a liquid form.

100 parts		Azot.	Oxygen.		Azot	Oxygen.
Pale nitric acid - -	contain of	29.50	70.50	or, in the proportion of	1	2.389
Bright yellow acid -		29.90	70.10		1	2.344
Orange coloured - -		30.37	69.63		1	2.292
Dark green - - - -		30.92	69.08		1	2.230

The quantities of true nitric acid (or that produced in the aeriform ſtate by ſaturating nitrous gas with oxygen) in ſolutions of different denſities is thus given, being inferred from mixtures of the ſtandard liquid acid with known weights of water.

100 parts of Nitric Acid of ſp. gr.		True Acid.	Water.
1.5040	contain	91.55	8.45
1.4475		80.39	19.61
1.4285		71.65	28.35
1.3906		62.96	37.04
1.3551		56.88	43.12
1.3186		52.03	47.97
1.3042		49.04	50.96
1.2831		46.03	53.97
1.2090		45.27	54.73

The dilute nitric acids undergo ſimilar changes by nitrous gas as the concentrated, but the quantity of gas which the acid is capable of abſorbing diminiſhes in proportion to the degree of dilution. Mr. D. found that 330 grs. of acid of 1.36 ſp. gr. became blue green after 50 cubic inches of gas had been paſſed through it, and the ſpecific gravity was leſſened to 1.351. It had gained in weight but 3 grains and when heated only 7 cubic inches of nitrous gas were collected.

There is a difficulty in accounting for all the changes of ſpecific gravity in the experiments above mentioned. Nitric acid undoubtedly loſes ſpecific gravity by abſorbing nitrous gas, and by a direct experiment a pale acid of 1.504 was reduced to 1.474 by compleat ſaturation with the gas. And on the other hand the ſame acid of 1.474 after being heated and brought to the ſtate of the pale nitric returned to the ſpecific gravity of 1.502 or nearly to its original weight. But on the other hand the yellow acid of 1.5 *loſt* ſpecific gravity by loſing nitrous gas and was reduced to 1.491. Probably this apparent contradiction depends upon the variable quantity of nitric acid united with the nitrous gas in the form of nitrous vapour, in which it always exiſts when expelled from the coloured acids.

Mr. Kirwan in his excellent experiments on the ſtrength of acids purſues the following method in eſtimating the quantity of *real acid* in ſolutions of nitric acid of different denſities.

The ſpecific gravity of the moſt concentrated nitrous acid which he could produce was 1.5543 in the temperature of 60°. This was highly fuming and yellow, and therefore conſiſted of nitric acid holding nitrous gas in ſolution. This laſt circumſtance however is neglected. He conſiders this as the *ſtandard acid:* and by calculations which will be given in the appendix he deduces the proportions of ſtandard in 100 parts of diluter acids whoſe ſpecific gravity is given. Thus for example, 100 parts of an acid of 1.4731 ſp. gr. are found by calculation to contain 90 parts of the ſtandard acid of 1.5543 and 10 parts of water. But the ſtandard itſelf is a mixture of water with an unknown quantity of *real* acid, and to determine this quantity Mr. Kirwan purſues the following method which is applied (*mutatis mutandis*) to the other acids.[1] Firſt, a known quantity of alkali is ſaturated with an acid whoſe ſpecific gravity is known, and whoſe proportion of ſtandard acid was determined by previous calculation. Then another ſolution is made of a known quantity of the ſame neutral ſalt as that produced by the union of the acid and alkali employed, and both ſolutions are brought to the ſame ſpecific gravity by adding water to the heavieſt. This gives two ſolutions which may be preſumed to hold equal quantities of neutral ſalt, and the quantity of ready-formed ſalt in one of the ſolutions is known by actual experiment, and the quantity of alkali and ſtandard acid required to make this quantity of neutral ſalt in the other ſolution is alſo known by experiment. From theſe data the quantity of real acid in the ſtandard may be readily inferred, underſtanding by the term *real* acid an acid of the degree of concentration that exiſts in the dry neutral ſalt combined with the alkali. An example will render this clearer

[1] Iriſh Tranſ. vol. iv. p. 17 and 35.

to the reader. A quantity of concentrated ſoda was heated to redneſs in a ſilver crucible whereby all the water of cryſtallization was expelled, and it was then diſſolved in ſuch a quantity of water that 367 grs. of the ſolution contained 50.05 of the dry alkali. This quantity was then ſaturated with 147 grs. of nitric acid of 1.2754 ſp. gr. and which contained 45.7 per cent. or 66.7 of the ſtandard acid of 1.5543 ſp. gr. The carbonic acid loſt by the ſolution was 14 grs. ſo that the quantity of ſoda alone in it was 50.05—14, or 36.05 grs. The ſolution was then lowered by water to 1.0401 ſp. gr. which was found by a ſeparate experiment to be the degree of denſity of water containing $\frac{1}{16.901}$ of its weight of dry nitrated ſoda. The firſt ſolution weighed 1439 grs. and hence it muſt have contained $\frac{1439}{16.901}$=85.142 grs. of nitrated ſoda. The quantity of ſoda employed was 36.05 grs. and the quantity of ſtandard acid was 66.7 and the ſum of theſe is 102.75. But of this quantity only 85.142 entered into the combination of the ſalt and therefore the difference between 85.142 and 102.75, or 17.608, muſt have been the mere watery part contained in the 66.7 grs. of the ſtandard acid. Therefore 100 of the ſtandard acid contain 26.38 of water and 73.62 of *real* acid or ſuch as exiſts in combination in dry nitrat of ſoda: and 100 parts of this ſalt contain 42.35 of alkali and 57.65 of real acid, which is equivalent to 78.33 of the ſtandard.

In theſe experiments on nitric acid it becomes a queſtion to determine how far changes of temperature affect the ſpecific gravity. Mr. Kirwan found that the ſtrongeſt acid was the [illegible] by heat and contracted by cold. From the reſult of many experiments he finds that on an average the variation of ſpecific gravity for every ſingle degree between 60° and 70° in an acid whoſe denſity at 60° is from 1.3 to 1.4 is .0005 and for the variation between 44° and 60° is .0064. An acid of 1.263 ſp. gr. at 60° gains loſes for every degree between 60° and 70° .00043, and for every degree between 60 and 45° the variation is .00036.

The affinities of nitric acid for the alkalies and earths are in the following order, barytes, potaſh, ſoda, ſtrontian, lime, magneſia, ammonia, glycine, alumine, zircon.

The combinations of the nitric acid with alkaline earthy and metallic baſes, are called Nitrats, and will be deſcribed in their proper place.

The ſame theory that ſuppoſed the ſuperior degree of oxygenation of the pale nitric over the coloured nitrous acid, has given the term *nitrites* to the ſalts of the latter acid. But this is founded on an erroneous idea of the difference between the two acids, and of the whole imagined genus of nitrites, the nitrite of potaſh alone has been ever produced, and this not by the direct combination of the nitrous acid and potaſh but by the partial decompoſition of common nitre. Its properties will be mentioned under the article *nitrite*.

NITRO-MURIATIC ACID. *Aqua Regia. Konigwaſſer*. Germ.

The term nitro-muriatic acid is not meant to deſignate any particular acid or modification of acid but ſimply a mixture of nitric or nitrous and muriatic acid, or ſometimes muriat of ammonia, which when united produce a very important agent in many chemical operations. It is particularly as a ſolvent for gold that this combination (which is very ancient) has been known, and hence it was termed by the alchemiſts *aqua regia*, (gold being with them the *king* of metals) and is nearly the only ſubſtance that can diſſolve this noble metal. The compoſition of the aqua regia fitted to diſſolve gold has been deſcribed under that metal. Platina alſo, like gold, is inſoluble in either of theſe acids ſingly, but yields to a mixture of the two, but in different proportions. Antimony alſo is ſcarcely ſoluble in any acid but the nitro-muriatic, and the compoſition of the mixture the beſt fitted for this purpoſe is ſtill different from the others.

Berthollet in his excellent and profound eſſay on chemical ſtatics has ſome good obſervations on this acid. When pale nitric and muriatic acid are mixed, an efferveſcence quickly takes place, the liquid becomes of a high amber-red colour, and a very pungent vapour is extricated, obviouſly ſmelling very different from the vapour of the nitrous or muriatic acid ſingly, but cloſely reſembling the oxymuriatic acid gas, which is the actual vapour given off. This is formed by a partial decompoſition of a portion of nitric acid which ſurrenders part of its oxygen to the muriatic acid gas, whilſt the remainder is nitrous gas, which diſſolving in the acid gives the high colour, and may be driven off by ſaturating the acid with an alkali or earth. The above decompoſition of nitrous acid, and evolution of oxymuriatic acid ceaſes when the mixed acid is ſaturated with the nitrous gas, and hence the fuming nitrous acid which already contains much nitrous gas, gives leſs oxymuriatic vapour than the pale acid. If nitrous gas be mixed with oxymuriatic acid gas over mercury or over very little water, the nitrous gas

takes the excess of oxygen from the oxymuriatic, and vaporized nitrous acid succeeds, but if sufficient water be present, this acid vapour, together with the muriatic gas separated from the oxymuriatic, is absorbed by the water, and liquid nitro-muriatic acid is produced.

Dr. Priestley[a] has found that a very powerful aqua regia which dissolves gold with great rapidity may be formed by impregnating liquid muriatic acid with the nitrous acid vapour (described in the last article). The proportion of constituent parts here widely differs from those of the common aqua regia for gold, which last is usually made by three fourths of nitric and one fourth of muriatic acid; whereas in making the other acid the liquid muriatic acid hardly increases in bulk by saturation with the nitrous vapour. Dr. P. also tried to form a nitro-muriatic acid that would dissolve gold by impregnating nitrous acid with muriatic acid gas, but without success, as the liquor would not touch this metal. As soon as the muriatic acid receives the nitrous vapour it changes from a pale straw to a deep orange, much deeper than nitrous acid alone can be brought to.

When nitro-muriatic acid is saturated with an alkali the nitrous gas which it had absorbed is given out, and the liquor duly evaporated gives both a nitrat and muriat of the alkali used. But when the acid is saturated with a metal the resulting salt is usually a simple muriat, the nitric acid having been employed to oxygenate the metal and thus to render it (in most instances) soluble in the muriatic acid, to which most metallic oxyds have the strongest affinity.

NITRAT OF POTASH. Nitre. Saltpetre.

Nitre is a neutral salt composed of nitric acid and potash in a state of perfect mutual saturation. Its primitive crystalline form is that of a rectangular octohedron, composed of two pyramids applied base to base, in such a manner that two opposite sides of the upper pyramid form with the corresponding sides of the lower one angles of 120°, while the two other opposite sides form with their corresponding ones angles of 111°. This figure however is of very rare occurrence. When the summits of the pyramids are deeply truncated, the result is a bevilled rectangular table, which is by no means unfrequent. But the most usual form which this salt assumes is that of the common quartz crystal, viz. a strait six-sided prism terminated at each extremity by a six-sided pyramid. The specific gravity of nitre according to Newton, is = 1.9, according to Muschenbroek, = 1.901, and according to Hassenfratz, = 1.9369:[b] the latter of these estimates seems to be the least correct. It has a sharp saline and cooling though disagreeable taste. When fully crystallized it is very brittle, and the larger prismatic crystals if held in the warm hand, will crack across with a very audible noise. It generally attracts a little moisture on exposure to the air, but this is probably to be attributed to the casual mixture of a small portion of deliquescent salt. With regard to the degree of solubility of nitre in water of different temperatures, there exist some contradictions that require to be cleared up: according to Bergman, this salt is soluble in seven times its weight of water at the usual temperature, and in about its own weight of boiling water; from the experiments of Hassenfratz however it appears that a hot saturated solution of nitre, after being cooled down to 61° Fahr. and remaining at this temperature 24 hours, holds nearly $\frac{1}{4}$ of its weight of salt, and at 54° Fahr. about $\frac{1}{6}$ of its weight: according to Beaumé,[c] 4 ounces of boiling water will take up 10 ounces of nitre when the solution is made in a matrass, but if a bason or any other open vessel is made use of, a pellicle begins to form at the surface of the liquor when it contains water and salt in equal proportions. The following table of the specific gravity and composition of solutions of nitre in water at 61° Fahr. has been constructed by Hassenfratz.[d]

Sp. gr. of solution at 61° Fahr.	Proportion of Nitre in 100 parts of solution.
1.006	1
1.012	2
1.018	3
1.024	4
1.030	5
1.035	6
1.040	7
1.046	8
1.053	9
1.059	10
1.065	11
1.072	12
1.078	13
1.085	14
1.091	15
1.098	16
1.105	17
1.111	18
1.118	19
1.125	20

[a] Obs. on Air, vol iii. p. 146. [b] Ann. Ch. xxviii. p. 16. [c] Chem. exper. i. p. 414. [d] Ann. Ch. xxvii. p. 135.

Sp. gr. of solution at 61° Fahr.	Proportion of Nitre in 100 parts of solution.
1.132	21
1.138	22
1.145	23
1.152	24
1.158	25

If a saturated solution of nitre is boiled strongly, and more especially if the boiling temperature is raised by the addition of any deliquescent salt, a very notable proportion of the nitre is volatilized with the water, as will be mentioned more particularly in the latter part of this article.

Nitre is readily fusible at a heat almost equal to that of melting zinc, or somewhat below ignition, and may be kept for a considerable time at this temperature without undergoing any change, except a slight loss of weight from parting with its water of crystallization; a piece of charcoal may even be immersed in it without producing any detonation. When poured out on any flat surface it presently congeals into a white translucent mass, commonly known by the name of *crystal mineral.* If however the heat to which melted nitre is exposed be greater than that requisite for maintaining its liquidity, a decomposition begins to take place; bubbles of gas are disengaged, and by a high heat, continued as long as any air is extricated, the acid is entirely decomposed, and nothing but the alkaline base of the salt remains behind; the gas that first comes over during this process is tolerably pure oxygen, but the latter portions are largely mixed with azot. When this experiment is performed in an earthen crucible, the alkalization of the nitre takes place more speedily, on account of the affinity of the potash for the silex and alumine of the crucible, hence also as the heat increases a considerable part of the acid is set at liberty in a state of semi-decomposition, which accounts for the red fumes of nitrous vapour observed on this occasion by Beaumé. When the fusion is not continued long enough for the total decomposition of the nitre, the residue consists of free alkali, and a variable proportion of nitrite of potash.

The decomposition of nitre by heat is much more speedy, if some inflammable substance be present: in this case a rapid disengagement of light and heat takes place, accompanied by a loud hissing noise, which is called the *detonation of nitre;* the added inflammable matter combines with the greater part of the oxygen of the nitric acid, and is itself converted into an oxyd or acid; if the latter, it generally unites with the alkaline base of the nitre in proportion as its own acid is decomposed or driven off. Thus if a few grains of sulphur be projected on red-hot nitre the former immediately takes fire, burns rapidly with a reddish-purple flame, and is converted into sulphuric and sulphureous acid, at the expence of the nitric acid, which is more or less decomposed; the sulphureous acid mixed with nitrous vapour flies off, while the sulphuric acid remains behind in combination with the disengaged potash of the nitre, forming sulphat of potash. When the quantity of sulphur added is not sufficient to effect a total decomposition of the nitre, the result is a mixture of the two neutral salts, and was known among the old chemists by the name of *Glaser's polychrest salt*.

If instead of adding the sulphur by small parcels at a time to the nitre in fusion, the two ingredients are carefully mixed together in the proportion of five or six parts of the former to one of the latter, and the surface be then touched with a hot iron or any other ignited body, the detonation is much slower than in the former case, the nitric acid appears to be entirely decomposed, and a quantity of SULPHURIC ACID, much more than sufficient to saturate the alkali of the nitre, is produced.

The detonation of nitre with charcoal is very rapid, whether the charcoal is added to the nitre brought previously to a state of fusion, or the two ingredients are mixed together by pulverization, and then thrown into a crucible or any other vessel heated red-hot; an intense bluish flame is disengaged, accompanied by great heat and a white vapour, the nitric acid disappears, and the residual salt is sub-carbonat of potash. The rationale of this process is commonly thus explained: the charcoal combines with the oxygen of the nitric acid, and is itself converted into carbonic acid, of which a portion unites with the alkaline base of the nitre, while the rest is volatilized together with the azot produced by the decomposition of the nitric acid. From the experiments however of Mr. Davy* it appears, that the detonation of these two substances is by no means a process of such simplicity as is generally imagined. This able chemist having filled a glass tube with a mixture composed of 6 parts of nitre and 1 of charcoal, detonated it, and received the product in a jar inverted over mercury and containing a little water: after the operation the water

* Researches, p. 44.

was found to be sufficiently acidulous to restore the colour of red cabbage juice that had been rendered green by an alkali, thus indicating the presence of a little nitrous acid; but the same liquor when supersaturated by caustic potash or quick-lime, gave out a very sensible odour of volatile alkali, hence it appears to have contained acidulous nitrat of ammonia. The gas produced by the detonation being mixed with the carbonic acid separated by muriatic acid from the alkaline residue, was found to be composed of carbonic acid, nitrous gas, and azot, in the proportion by bulk of 20 of the first, 3 of the second, and 7 of the third.

If the charcoal in the detonating compound instead of being $\frac{1}{7}$ is raised to $\frac{1}{5}$ of the mass, no nitrous gas, and probably no nitrous acid is produced, which agrees with the observation of Macquer,[f] who expressly states that when successive portions of a mixture of nitre and charcoal are detonated in a distillatory apparatus, "nothing is found in the retort but the alkali which was the basis of the nitre; and the liquor contained in the receiver has no acid taste, does not redden the tincture of turnsol, makes no effervescence with alkaline matters, and is truly nothing but water which is sometimes slightly alkaline." The presence of ammonia in Mr. Davy's experiment may we think be satisfactorily accounted for by the decomposition of the water of crystallization by the charcoal, and the combination of its hydrogenous base with the azot of the nitric acid.

Those compound acids into which carbon enters as an essential constituent, decompose nitre with nearly the same energy as charcoal does: thus if equal parts of nitre and crude tartar are mixed together and ignited, a detonation takes place, the tartareous and nitric acids mutually decompose each other into carbonic acid and other gasseous products, and there remains behind sub-carbonat of potash, being the alkaline base of both salts. The alkali thus produced was in much request among the old chemists by whom it was named *white flux*, *extemporaneous alkali*, and *nitre fixed by tartar*: it is in no respect however different from purified pearlash if the nitre has been all decomposed.

Most of the metals if reduced to filings or powder and mixed with nitre will produce a detonation at a red heat; the metal in a state of high oxydation unites with the alkali, and the nitric acid is more or less compleatly decomposed. Those metals that are most inflammable produce the most violent detonation, such are zinc, antimony, tin, iron and bismuth.

The effect of pure hydrogen on nitre has not been examined, but those readily-fusible inflammable bodies into the composition of which it largely enters, are not capable of detonating with nitre except in exact proportion to the amount of carbon that they contain beyond what is requisite for the production of carburetted hydrogen, or, in the words of Macquer, to whom the discovery belongs, "no detonation will happen till the inflammable matter be burnt and reduced to a coal; then the detonation commences, and is always proportionable to the quantity of coal produced by the inflammable matter." Thus if oil, fat, resin, pitch, mineral tar, or camphor, are dropped upon ignited nitre, they burn with a large flame, but without producing those violent jets of fire that charcoal does, or hastening the decomposition of the salt. If a combustible substance of this class, but considerably mingled with charcoal, as asphaltum, be treated in the same manner, the carburetted hydrogen, as being the most inflammable, first burns off with a quiet flame, and then the remaining charcoal produces the usual phenomena of detonation.

Nitre is entirely decomposed by distillation at a moderate heat with sulphuric acid, and at a higher temperature with phosphoric, boracic, and arsenic acids; these combine with the alkali of the salt, while its acid passes over in the state of vapour; a similar effect is produced by silex or alumine, or a mixture of both, but the heat requisite in this case being considerably higher than in the former a proportionably larger quantity of nitric acid is decomposed during the process. Strong muriatic acid will also in part decompose nitre, as we have already shewn in our account of that substance.

The only substance capable of decomposing nitre so as to liberate its alkali, is caustic barytes, a quantity of each in fine powder being mixed together, and then moistened with a little water, re-act on each other and produce nitrat of barytes and caustic potash, of which the latter alone (if too much water is not used) remains in solution.

The exact analysis of nitre is attended with many difficulties, in consequence of which even the most able chemists vary materially in their accounts of its composition. Bergman found that 49 parts of potash when saturated with nitric acid afforded 100 of crystallized nitre. Hence he states the proportions of this salt at

[f] Chem. Dict. art. Clyssus.

49	Potash
33	Nitric acid
18	Water
100	

According to Wenzel 100 parts of nitre contain

48.13	Potash
51.87	Acid and water
100.00	

But according to Kirwan 100 parts of crystallized nitre dried at 70° Fahr. are composed of

51.8	Potash
44	Acid
4.2	Water
100.0	

and this estimate being incidentally confirmed by other experiments of Berthollet and of Keir, is probably very near the truth.[g]

The uses of nitre are very important. It is employed in prodigious quantities in the manufacture of gunpowder, and in all kinds of pyrotechnical compositions. It is the only salt from which nitric acid is habitually made, both in the large and small way; it is also largely consumed in the preparation of sulphuric acid from the combination of sulphur. When mixed with common salt it adds to the efficacy of this latter in preserving animal flesh from decay; it is employed by the glass-maker and the goldsmith, and is in constant use in the laboratory.

* * * *

We now proceed to treat of the natural history and manufacture of nitre, as carried on in various countries, but chiefly in France, where its production has been more an object of philosophical investigation than in any other country.

Nitre may be considered both as a natural and artificial product. Native nitre mineralogically speaking, is a substance of very recent formation. It appears to occur in two different repositories: the first of these is limestone, and the second vegetable soil. The calcareous repository is either a peculiar variety of secondary floetz limestone, or calcareous tufa, or chalk, or indurated marl. In these rocks it occurs as a thin granular crust, or an efflorescence of minute spicular crystals overspreading the outside, and particularly lining the inside of the caverns both natural and artificial, with which these rocks abound. Hence probably is derived its ancient name saltpetre (*Sal petra*, rock salt). Calcareous strata containing nitre, are found in various parts of South America, in some districts of France, in the county of Bamberg, and at Hamburg near Wurtzburg. But the most celebrated repository of native nitre is the Pulo of Molfetta, in the province of Puglia, in the kingdom of Naples. The Pulo is a deep cavity in the form of an inverted cone, produced by the falling in of several large natural caverns, and communicating laterally with other caverns both natural and artificial, that yet remain entire. All the strata in which these excavations occur are of hard secondary limestone, abounding with the remains of organized bodies. The whole of these caves at the time when the Abbé Fortis called the public attention to them, were lined with an efflorescent crust of nitre more than an inch in thickness, which after being scraped off, was again renewed in the course of a few days in constant succession. Thin fragments of stone were often falling down, being forced from their place by the crystallizations of nitre beneath them; the substance of the rock also to the depth of a foot or more from the surface, was richly impregnated with the salt which might be separated by lixiviation; but specimens taken from a greater depth seem to contain no nitre ready formed, at least boiling water was incapable of dissolving out any. It appears however from the testimony of Dolomieu, that a piece of this rock after lying for two months in a dry cabinet, became covered with a thin crust of nitre. Specimens of the nitrous crust from the Pulo have been analysed both by Klaproth[h] and Pelletier,[i] and the results agree full as well as can be expected in the examination of a substance so liable to slight variations in its composition.

Klapr.		Pellet.	
425.5	—	407.5	Nitre
2.	—	——	Muriated potash
		26.7	Muriats
		20.8	Sulphats, soluble in cold water
254.5	—	96.7	Sulphat of lime.
304.	—	410.	Carbonat of lime
986.0	—	961.7	
14	—	38.3	Loss
1000.	—	1000.	

[g] Kirwan on Acids (Additional Obser.) p. 70. [h] Analyt. Ess. I. p. 273. [i] Mem. de Chem. II. p. 477.

The second repository of native nitre is vegetable soil. It is asserted by some chemists, especially those who maintain that nitre is a product of vegetation, that all soils contain nitre in proportion to their fertility: this however is by no means the case: Mr. Beaumé lixiviated carefully 36 specimens of fertile soil, and did not obtain a particle of nitre from any one of them.[k] There is no country in Europe the soil of which is so rich in this salt as Spain. It is asserted by Bowles that nearly a third of the uncultivated lands in the Eastern and Southern provinces of this kingdom afford it in abundance under the following simple management. The land is ploughed twice or thrice during the winter and spring, to the depth of three or four inches; it lies fallow the whole summer, and about the middle of the autumn the soil having been thus exposed to the full action of the air, is carted off and lixiviated: the liquor is then boiled down in the usual manner, and affords by cooling a quantity of nitre mixed with from 20 to 40 *per cent.* of common salt.

A considerable part of the soil in Lower Hungary is richly impregnated with nitre, and several of the wells and springs are incapable of being used as drink on account of their containing from $\frac{4}{5}$ to 4 *per cent.* of this salt.[l]

Many of the lands in India, especially in the vallies of the great rivers, are exceedingly abundant in nitre. In the presidency of Calcutta alone between 7 and 8000 tons are annually manufactured. Sometimes it covers the surface of the soil with a saline efflorescence, which being swept off is renewed every other day at particular seasons of the year. The soil of those lands in which it is less abundant is raked up into small heaps, and mixed with the scrapings of roads and cattle-stalls, and after being exposed for a certain time to the action of the air is lixiviated: the earthy residue is mixed with fresh earth, and after two years affords as large a produce of nitre as at first.

In many nitrous soils the acid which they contain is combined for the most part with lime instead of potash, so that the produce of real nitre which they afford by the usual mode of treatment is very small: long experience however has taught the nitre-makers in every country where these soils occur, to remedy this defect by the addition of wood-ashes. The rationale of this, though wholly unknown to the greater number of those who practise it, is sufficiently obvious to the chemist; the carbonated alkali of the ashes and the calcareous nitrat of the soil mutually decompose each other, and carbonated lime and nitrated potash is the result. Many of the nitrous soils in India require this alkaline addition, as well as those of China and other parts of Asia. Much of the nitrous soil in the Crimea and Ukraine also is of this description: in appearance it resembles common black vegetable mould, except that it is more unctuous to the touch, and is so light and of such little coherence as to be converted to a loose dust by a few days of dry weather. Those parts of the Crimea that have been long uncultivated, and especially the artificial mounds that have served for burial places and the sites of towns, are selected by the nitre-makers. The soil being dug up is mixed with about $\frac{1}{5}$ by measure of wood-ashes, and lixiviated in perforated casks in the usual way: the liquor thus produced, when concentrated by repeated lixiviations, is mixed with the mother water of a preceding crystallization, and boiled down for 24 hours, removing from time to time the common salt and muriated potash that separates during the process; it is now transferred while hot into shallow coolers, in order to crystallize, which it does in 24 hours more. The rough crystals being drained are again dissolved in water, and the product of the second crystallization is a nitre somewhat impure but yet in a fit state for the market. Four hundred cubic feet of the mixture of earth and wood-ashes afford 42 lbs of nitre of the first crystallization, which by the subsequent refining is reduced to 39 lbs.

Before the general use of gunpowder in war, the produce of native nitre was abundantly sufficient to supply the European demand for this article; but when in consequence of the universal adoption of fire-arms the consumption of this salt was prodigiously increased, it became an important object for every nation, and especially those that were the least commercial, to encourage by every method the domestic manufacture of nitre. Every kind of soil that had the least resemblance to the nitre soils of Spain and India, was examined by lixiviation, and by degrees it was ascertained that the surface soil of farm-yards, of cattle-stalls, of cellars, of privies, and other places long exposed to the vapours of putrefying animal matter, afforded, when mixed with wood-ashes and lixiviated, a considerable quantity of nitre. It was also discovered that the plaister, mortar, and what is included under the general term brick-rubbish of old houses, was capable of yielding this

[k] *Mem. de Scavans Etrang.* XI. p. 382.

[l] Ruckert, Journ. des Mines, No. 2, p. 12.

salt by a similar treatment. In consequence of this discovery all these substances were claimed by the crown in most of the countries of Europe, and granted to societies of saltpetre-makers, incorporated for the purpose of supplying the public magazines of the country with this indispensable commodity. England and Holland were soon able to supply themselves at an easy rate with nitre, by means of their commercial connexions with India and China, and therefore attended only a very short time to the domestic preparation of this salt. France, Germany, and the Northern states of Europe on the other hand, importing but a small quantity of nitre in proportion to their wants, have always encouraged its manufacture by every method in their power. In the former of these countries, especially, the privileges of the saltpetre-makers were so extensive and so rigorously enforced, as to occasion much petty tyranny and vexation, besides operating as a direct discouragement to agriculture. These manufacturing companies were allowed to take away without compensation all the nitrous soils that they could discover: hence when a house was pulled down, such part of the old materials and foundation soil as suited their purpose was selected from the rest and carried off by them; they had also the right of digging up once a year the earthen floors of every out-house, and in some provinces even of the inhabited cottages: the farmer's yards were subject to the like troublesome visitations, by which he was deprived of a considerable quantity of his best manure; and every parish or district was obliged besides to furnish a certain amount of wood-ashes. These terrible means of annoyance were placed by the crown in the hands of the farmers general, and by them were entrusted to inferior agents, more disposed to exercise them so as to obtain from those in their power a pecuniary composition, than to exert their privileges for the public advantage; the consequence of which was that notwithstanding the trouble and extortion by which individuals were thus severely harassed, the annual produce of nitre at the accession of Turgot to the ministry, scarcely exceeded one half of what it had amounted to half a century before. An important reform however was introduced by this able statesman, the privilege of digging up the floors and cellars of inhabited houses was abolished, the requisitions of fluel and wood-ashes were restrained, and the administration of this department was taken from the farmers general, and entrusted to a particular commission, of which Lavoisier and Clouet were leading members; a considerable sum of money was placed at the disposal of the Royal Academy of Sciences, to be distributed as prizes by this body to the authors of the best memoirs on the preparation of saltpetre, in consequence of which various important changes took place in the management and construction of artificial nitre-beds, and the refining of their produce. By these means the yearly amount of nitre made in France was increased during the period from 1775 to 1785, from 1,800,000 lbs. to 3,500,000 lbs. Four years after this period the Revolution war commenced, for the supply of which a prodigious quantity of gunpowder was demanded, while all the requisite nitre was obliged to be drawn from domestic supplies. To meet this exigency the knowledge and personal superintendance of the ablest chemists of Paris was directed to this important object, and in the space of a very few years the produce of nitre was more than quadrupled, and a simplicity and expedition introduced into the refineries of this salt, that seem to have brought its manufacture nearly to perfection.

In our account of nitric acid we have shown that the component parts of this substance are azot and oxygen, we have also shown in another place that animal matters in general contain a large quantity of azot combined in various proportions with hydrogen, carbon and other substances. When the decomposition of animal matter by means of the putrefactive fermentation takes place, its elements enter into new combinations with each other and for the most part assume the gaseous form. Now although azot like several other bodies when it has compleatly acquired the state of elastic fluidity is but little disposed to combine with oxygen at the usual atmospheric temperature, yet when in its nascent state and particularly when mixed at the same time with easily combustible substances it unites with oxygen without much difficulty. Hence it is obvious how nitrous acid or more probably nitrous vapour is produced by the contact of atmospheric air and putrid gas. But the acid is produced slowly, and in proportion as it forms will fly off together with the other volatile ingredients, except it meets with an alkaline base to combine with into a neutral salt. It might seem, *a priori*, a matter of perfect indifference, as far as the mere formation and detension of nitrous acid is concerned, whether one alkaline substance or another was employed for this purpose, but experiment has shown, as we shall detail more at large presently, that the proper fixed alkalies whether in a mild or

caustic state are by no means so efficacious as carbonat of lime. Thus it appears that three conditions are requisite for the production of nitrated lime (from which by the subsequent addition of carbonated potash common nitre is readily obtained) viz. animal matter in a state of decomposition, atmospheric air, or rather the oxygenous part of it, and carbonated lime.

The first proposal for the construction of artificial nitre beds came from Glauber. This able chemist reflecting on the circumstance that earth which had been long exposed to exhalations from the dung and urine of sheep and other animals, or in which animal bodies had been buried was capable of affording nitre by lixiviation, concluded that this salt was contained in animal matter: but finding that various animal fluids such as urine and blood, afforded no nitre when recent, he was induced to try the effect of putrefaction on them: for this purpose he filled an open vessel with blood, and exposed it to spontaneous decomposition till nothing remained of it but a loose earth: from this by lixiviation he obtained a portion of nitre, hence he concludes that the salts contained in recent animal matter are in an inert or as he calls it a dead state, till by long exposure to the air and fermentation they acquire from it a vital spirit.[m] From the nitrous efflorescences on the plaister of cellar walls he inferred that the saline base of nitre was also contained in certain earths; and because that part of the plaister in immediate contact with the bricks, and therefore excluded from the air, afforded no nitre by lixiviation, he drew the same conclusion as in the former case respecting the *vivifying* influence of the air in the formation of nitre. It being a matter of common notoriety that earth when long impregnated with the lees of wine became rich in nitre, this circumstance together with other collateral arguments induced him to infer the presence of nitre in vegetables also. In pursuance of this theory he proposes the following plan for the formation of nitre.[n] Let a large square wooden vat be made open at top, and with a perforated false bottom placed a few inches above the real bottom; and between the two bottoms let a pipe with a stop cock be inserted so as to discharge any liquor into a shallow open reservoir sunk into the ground just in the front of the vat: on the opposite side of the reservoir let another vat similar to that already described be placed, and, to compleat the apparatus, let a pump be fixed in the reservoir by which its contents may be transferred to either of the vats that the workman chooses. Every thing being compleat let the vats be filled with horses', cows', or sheeps' dung mixed with leaves or any dry vegetables: then draw a weak alkaline ley from quicklime and woodashes and pour it into one of the vats till it stands a finger's breadth above the other ingredients. In about 12 hours time turn the cock and let the liquor drain into the reservoir, whence it is to be pumped again into the other vat, and after 12 hours more returned into the reservoir. In the space of a few days the contents of the vats will heat and ferment strongly: no further care is required till the decline of the fermentation, which may be known by the cessation of the steam: the materials are then to be again drenched with the liquor in the reservoir for 12 hours, and when this is again discharged the fermenation will recommence. This method being pursued for ten or twelve months, (taking care to keep the vats filled with fresh portions of leaves and dung as the mass subsides) both the liquor and the contents of the vats will be found to be very rich in nitre.

The above method of Glauber's deserves notice as the first attempt at the artificial manufacture of nitre, although there is little doubt that its success is greatly exaggerated, as is but too much the custom of this author. Another method proposed by the same chemist and the success of which is better authenticated is the following. Construct a vault of frame work of any dimensions and line it to the thickness of three or four inches with plaister composed of the following materials, viz. one part of quicklime, one of woodashes, and two of cow's or horse' dung with a sufficient quantity of urine to work it up to a proper consistence. This plaister being carefully applied is to be dried by a gentle fire to be made under the vault, a second coating of the same materials is then to be put on, and thus by alternate drying and plaistering the vault is to be made two or three feet thick. Being now sufficiently strong the wooden framing may be removed. The plaister in proportion as it dries is to be restored to a proper state of moisture by the application of urine, and in the space of a few months, more or less according to the warmth of the air and other circumstances, the whole inside of the vault will be covered with nitrous efflorescences: by degrees the plaister will be impregnated with nitre through its whole substance, at which time the vault being broken down and

[m] German. Prosperit. part I. p. 103

[n] Ditto, part III. p. 7.

its materials being duly lixiviated, a large quantity of nitre will be obtained. This method was adopted in many parts of Germany with reasonable success, but requiring much manual labour was at length abandoned for more economical processes.

In direct opposition to the instructions on this subject by Glauber who had clearly shown the absolute necessity of the presence of air to the formation of nitre, several very large experiments were made, chiefly in Sweden and Germany to prepare this salt by filling large trenches with animal and vegetable refuse of various kinds mixed with quicklime and wood ashes and duly watered with urine. But though all other circumstances, were tolerably favourable the exclusion of air from the greater part of the mass so delayed the production of nitre, that after the expiration of 20 years a smaller quantity of this salt was thus obtained than is yielded by the same materials in two or three years when the air is freely admitted to them. Attempts were made to remedy these defects by the insertion of pipes and air shafts, but with little success compared to the trouble and expence; so that at length, instructed by experience, the Swedes adopted that mode, which with a few modifications they still retain, and the advantages of which are daily more and more apparent. Upon a square floor of brick or stone, is laid a bed a few inches thick composed of woodashes, lime, and mellow vegetable earth moistened with urine, and the mother water obtained in the refining of nitre: upon this is placed a layer of straw or old thatch, then another of the composition, and so on alternately till a pyramid 8 or 9 feet high is constructed. In order to preserve these piles from the rain and snow which would wash out the salt as fast as it formed, a number of stout poles are stuck in the ground all round the floor, the tops of which are tied together, and their interstices carefully closed with intertwisted twigs, thus excluding the rain, but admitting the air. These pyramids are watered from time to time with putrid urine, and in about a year saline efflorescences begin to appear on their surface: shortly after, the nitre thus generated is swept off, and the piles then yield regular crops of this substance every week or ten days, except during frosty weather, for about nine years. At the expiration of this period the efflorescence ceases, and the nitre yet remaining in the pile is obtained by lixiviation: the insoluble residue is an excellent manure and much in request for flax and hemp. In Prussia, nitre is obtained from mud walls composed of loamy earth, night soil, mud from ponds, stable litter, and any other vegetable or animal substances: these being mixed together and tempered to the consistence of stiff mortar by urine and dunghill drainings, are raised into walls four feet high and about two feet thick, and topped with a slight coping of thatch in order to shoot off the rain: in process of time the straw and other vegetables which the walls contain decay, by which it is rendered more porous and the air gets admission more or less to its interior substance. Many however are the objections to this method of preparing nitre. In the first place the labour required for the construction of these walls is very considerable: secondly, the clayey loam which is necessary to give the mass a due consistence for the formation of walls, prevents it from being sufficiently porous even after the straw, &c. has decayed: thirdly, there is seldom a proper quantity of calcareous matter, so that much of the nitrous acid flies off for want of a fit base to detain it: and fourthly, the very imperfect protection from the weather which these walls receive from their thatch coping, subjects a considerable quantity of the salt when formed to be washed out by the rain and thus lost. For these reasons it is seldom worth while to lixiviate this earth oftener than once in about six or eight years, and even then the produce is very scanty.

In France the nitre-beds are composed of nitrous earth from farm-yards, stables, &c. of street sweepings, of mild calcareous earth, such as old mortar or plaister, chalk, tufa, or the sweepings of roads paved with limestone; of animal matter, such as night-soil, blood, refuse from the skinners and tanners, bones and other offal; of vegetable matter, such as straw and stable litter, leaves, sawdust, spent tanner's bark, &c. These are all mixed in somewhat casual proportions, care being only taken that a sufficient quantity of calcareous matter is present; they are laid as lightly as possible in long beds or pyramids under covered roofs to protect them from the weather, and are kept duly moistened with putrid water or urine: by this management they yield every other year by lixiviation a considerable quantity of nitrated lime, which by the addition of woodashes or potash is converted into true nitre. The circumstance in which the French nitre beds differ principally from those of Sweden and Germany is that they scarcely ever contain woodashes, the requisite portion of alkali being added in a subsequent part of the manufacture.

The proportion of nitre afforded by these artificial beds it is not easy to ascertain. In France, where the custom is to lixiviate once in two years, the produce may be estimated at from 7 to 12 ounces of nitre from 100 lbs. of materials: of this about half is nitrat of potash, and the rest nitrat of lime, requiring therefore the addition of potash to convert it into true nitre.

Concerning the theory of nitrification much has been written, but with the exception of an admirable memoir by M. Thouvenel, to little purpose. The chemists of the modern school having discovered that nitric acid is composed of oxygen and azot, and that animal matters abound in condensed azot, content themselves with saying that the azot as it is evolved by the progress of putrefaction combines with the oxygenous part of the air, and thus forms nitric acid, which is prevented from escaping by the lime and other alkaline bases with which it is in contact. This however from the little hitherto known on the subject appears to be a very imperfect representation of the matter; we shall therefore proceed to detail the principal results of M. Thouvenel's experiments, which, imperfect as they are, throw more light on this curious and important subject than any others with which we are acquainted.*

Several open vessels containing each three lbs. of pure and well washed chalk moistened with distilled water, were for the space of seven or eight months exposed to the putrid vapours of privies, cellars and prisons, being then lixiviated they afforded from 50 to 90 grs. of nitre each, of which the principal part was nitrat of lime but mixed in general with a little nitrat of potash. From other similar experiments M. Thouvenel ascertained that in close confined situations where there was hardly any circulation of air, and on the other hand that in places where the external air passed in a free current, the production of nitre was by no means so copious as where the putrid fumes remained for a long time in contact with the chalk, and were only occasionally diluted with atmospheric air. In those places most favourable to the generation of nitre were exposed together with the vessels containing chalk, others with a like quantity of quicklime, with magnesia both mild and caustic, with earth of alum and with the fixed alkalies both mild and caustic. They were all examined after the expiration of 8 months: the saline contents of the chalk we have just mentioned; the quicklime, the caustic and mild magnesia afforded from 6 to 7 grs. of earthy nitrat mixed with a little ammoniacal nitrat; the earth of alum yielded a still smaller proportion of nitrat, and the fixed alkalies none at all. The results of these experiments being ascertained, another series was undertaken and conducted in the following manner. An earthen cucurbit was fitted to a very large receiver of the same materials pierced with a few small holes so as to allow of a partial communication between its contents and the outer air: in the cucurbit was put some putrid blood, and in the receiver were placed open vessels containing a few ounces of lime, magnesia, earth of alum, and the fixed alkalies both mild and calcined: 21 other receivers furnished in the same manner were connected with cucurbits charged with various putrescent mixtures. The gas as it was disengaged from the materials in the cucurbit passed into the receiver mixing with the atmospherical air, and surrounding the inclosed earth and alkalies. After this process had been continued for a year or more the contents of the receivers were examined; in all of them the chalk was found to contain nitrat of lime but varying in proportion from one to 5 grains per oz. The quicklime, the magnesia and earth of alum in most of the experiments had acquired no nitric acid, but in some a little earthy nitrat was formed. The fixed alkalies, as in the former experiments, had acquired no nitric acid whatever. It was further observed that although the chalk in most of the experiments showed signs of nitrification in about a month's time and proceeded rapidly for the first three months, yet after this period the progress was very slow, no doubt because the oxygen of the atmospheric air originally contained in the receivers having been consumed, the gradual pouring in of putrid gas from the cucurbit almost entirely preventing the external air from entering through the small holes that had been drilled for this purpose.

It appearing from the above experiments that the fixed alkalies and the alkaline earths themselves when caustic are very little capable of absorbing nitric acid from a mixture of putrid gas and atmospheric air, M. Thouvenel was induced to try whether this was owing to any change produced on the putrid gas by these bodies. For this purpose having charged a retort with putrefying materials, he connected with it three receivers in the manner of Woulfe bottles, the last of which terminated in a tube communicating with a pneumatic apparatus. Four different sets of this apparatus were employed at the same time. In the first of these,

* Mem. Etrang de l'Acad. des Sciences xi. p. 110.

the two receivers nearest the retort were charged with four ounces of chalk diffused in distilled water, while the third receiver contained a solution of caustic potash. In the second set the two first receivers contained distilled water, and the last was charged with the washed chalk. In the third set the two first receivers contained limewater; and in the fourth set a solution of caustic potash, the third receiver in both cases holding the chalk. They were all equally exposed to the same temperature, namely, from 74° to 80° Fahr. for six months, and the changes which their contents had undergone were then examined.

The chalk in the first apparatus afforded 26 grs. of nitrat of lime mixed with a little nitrat of ammonia; the potash in the third receiver had become saturated with carbonic acid and had partly crystallized on the side of the receiver, but contained no nitre.

In the second apparatus the water of the two first receivers had acquired a very putrid smell from the gas which had passed through it, and contained a little ammonia but afforded no nitrous salt on evaporation: the chalk in the third receiver afforded by lixiviation no more than 4 grains of nitrated lime.

In the third apparatus the lime water had deposited its earth in the state of carbonat, and the supernatant fluid had a strong odour resembling ammonia and putrid garlic: by evaporation it yielded 5 or 6 grains of nitrated ammonia. The chalk in the third receiver gave only a slight trace of nitrat of lime.

In the fourth apparatus the potash was crystallized but contained no nitre: with sulphuric acid it effervesced strongly, giving out a very pungent and highly fetid gas: the chalk in the third receiver gave no indications whatever of the presence of any nitrous salt.

The gas remaining in the receivers and collected in the pneumatic apparatus was in all the four experiments found to be slightly inflammable, although when rising from the putrefying materials it extinguished a taper immersed in it. This putrid inflammable gas was incapable by itself of nitrifying chalk, but when mixed with washed atmospheric air, carbonic acid soon made its appearance, and then the gas became capable of impregnating chalk with nitrous acid as at first.

The above experiments were undertaken when pneumatic chemistry had as yet made but little progress, and therefore the deductions from them are by no means equivalent to the labour and time employed in carrying them on: it appears however that we may legitimately draw the following conclusions. In the first place the formation of nitric acid from animal matter in putrefaction, is not owing to atmospheric air being presented to the azot when in a nascent state, for this change takes place after the azot and other gazefiable substances have actually assumed the elastic form. Secondly, the elements of the putrid gas are carbonic acid, azot, hydrogen and carbon, not mixed but combined together though weakly: this combination is in part destroyed by mere washing in water, but more compleatly by the action of those alkaline bases that are not compleatly saturated with carbonic acid; when the carbonic acid is abstracted, the further decomposition of this gas by atmospheric air tends more to the production of ammonia and carbonic acid than of nitric acid. Washed chalk after being thus nitrified often contains a little nitrat of potash as well as nitrated lime: it does not however hence necessarily follow that potash is also a product of putrefaction; for it may possibly pre-exist in the chalk in a state insoluble in water, as it does in leucite, in the alum ore of La Tolfa, and other minerals. The important practical conclusion to be deduced from these experiments is that the only alkaline substance to be admitted in the composition of nitre beds is mild calcareous earth.

Chalk however is not only capable of being nitrified by exposure to the combined action of atmospheric air and putrid gas, but also by means of the atmospheric air alone. On this subject there are some experiments by Lavoisier and Clouet, much to the purpose.[a] The village of Roche Guyon on the Seine, is situated on a ridge of chalk, which having the character of nitrifying spontaneously by exposure to the air, was on this account visited and particularly examined by the able chemists just mentioned. In order to ascertain whether this chalk before the action of the air contained any nitrous salt, selection was made of a part of the rock which had recently been laid bare by the falling down of a large mass. In this newly-exposed face of rock, a gallery had been driven, of which the further extremity had been excavated only two or three days before. In order to render the experiment as unexceptionable as possible, about a foot more of chalk was removed from the extremity of the gallery, after which a specimen of the weight of 12½ lbs. was dug out, and subjected

[a] Mem. Etrang. de l'Acad. des Sci. xi. p. 503.

to lixiviation: by evaporation of the fluid there were deposited 4 grains of muriated soda; and the small residue of mother water afforded by the addition of carbonated potash 53 grains more of salt, which appeared to be muriat of potash, with perhaps a slight admixture of nitre, for although it did not detonate in the smallest degree with charcoal, yet by sulphuric acid it gave out acid fumes, in which the odour of nitro-muriatic acid was just perceptible.

Hence 100 French lbs. of this chalk afford

		gros.	grains.
without Potash	Muriat of soda - - - - - - - - - - - -	0 —	32
with Potash	Muriat of Potash and a little nitre - - - -	5 —	64
		6 —	24

A similar specimen was taken with the same precautions from an adjoining gallery and lixiviated, the saline contents of which calculated on 100 lbs. amounted to

		gros.	grains.
without Potash	Selenite in small quantity		
	Mother water, which gave		
with Potash	Impure nitre - - - - - - - - - - - - - -	0 —	68½
	Muriat of potash - - - - - - - - - - - - -	1 —	38
		2 —	34½

Another specimen of chalk, taken from near the summit of a rock after having removed the surface to the depth of about two feet, afforded by lixiviation from 100 lbs.

		oz.	gros.	grains.
without Potash	A little selenite			
	Mother water, which gave			
with Potash	Nitre - - - - - - - - - - - - - -	1 —	2 —	24
	Muriated potash - - - - - - - -	0 —	1 —	10½
		1 —	3 —	34½

A specimen of chalk taken from the middle of a rock, after having removed the surface to the depth of two feet, afforded from 100 lbs.

		oz.	gros.	grains.
without Potash	A little selenite			
	Mother water, which gave			
with Potash	Nitre - - - - - - - - - - - - - -	5 —	5 —	19½
	Muriat of potash - - - - - - - -	0 —	1 —	70
		5 —	7 —	17½

A shallow cave that had been dug out of the chalk rock a considerable time before, was observed to be lined with saline efflorescences: after the outer surface had been removed to the depth of three inches, a specimen was taken, which afforded from 100 lbs.

		lbs.	oz.	gros.	grains.
without Potash	Nitre - - - - - - - -	0 —	10 —	1 —	52½
	Mother water, which gave				
with Potash	Nitre - - - - - - - -	0 —	10 —	1 —	52½
		1 —	4 —	3 —	33

The effloresced surface to the depth of three inches, of the same cave, afforded

		lbs.	oz.	gros.	grains.
without Potash	Nitre	1	5	7	31
	Mother water, which gave				
with Potash	Nitre	3	1	3	24
	Muriat of Potash	0	12	6	66
		5	4	1	49

A specimen from another shallow cave, after the outer surface to the depth of between three and four inches had been removed, afforded from 100 lbs.

		lbs.	oz.	gros.	grains.
without Potash	Nitre	0	8	0	0
	Mother water, which gave				
with Potash	Nitre	1	9	4	8
	Muriat of potash	0	5	4	51½
		2	7	0	59½

Hence it appears that the chalk composing these rocks, though perhaps not absolutely and entirely destitute of nitric acid even at their centre, is much more abundant in this substance in proportion as it is situated near their surface, and that the perfect nitre or nitrat of potash is only found near the surface of the chalk: a circumstance which seems to show that both the acid and alkali have been either deposited from the air, or formed by the contact of this latter with the chalk. In confirmation of this deduction may be mentioned an experiment by the Duc de la Rochefoucault, who lixiviated a considerable quantity of chalk, so as to dissolve out its saline contents, and then exposed it to the action of the air for fourteen months, during which period it had acquired not only nitric acid but potash, since the liquor of the second lixiviation deposited by evaporation a little nitre, and afterwards a considerable quantity more on the addition of potash. These facts having never been called in question, the next inquiry that occurs is whether the atmosphere furnishes the entire nitric acid or only one of the constituent parts of it? That this latter is the case might be inferred from the frequent occurrence of organic remains and impressions in chalk, whence this mineral may be supposed to be by no means destitute of animal matter. Against this however there may be alleged a direct experiment by M. Thouvenel, who on exposing some washed chalk for six or seven months to a portion of atmospheric air confined in a large receiver, and previously well *washed* in distilled water, found that not an atom of nitrat of lime was generated; while in a similar experiment in which washed chalk was exposed to *unwashed* air, a very sensible quantity of nitrated lime was produced. Now the washing could not separate the azot or oxygen, though it might and no doubt would take away any nitric acid ready formed, or any nitrous salt that might be contained in the atmosphere. It is observed of these chalk rocks that those parts that are adjacent to inhabited buildings yield a greater proportion of nitrat of *potash* than those which are at a distance from houses; a circumstance that seems to point out a probable source of the alkali without supposing it to be generated either in the air or chalk. It is well known that the common fuel in France is wood, therefore the air in the vicinity of houses must be more or less impregnated with pyroligneous acid contained in the wood smoke; but the acid vapour that flies off in the common method of preparing charcoal (and which is no other than pyroligneous acid) when collected in a proper apparatus condenses into a sour liquid from which by gentle evaporation a black residue is procured that yields by incineration a large proportion of potash, as we have shewn in our account of that substance, in the article Carbonat of Potash.

It only remains to give an account of the extraction of nitre from the earths in which it is contained, and of the purification of this salt.

The first thing is to assay the earth. This is done by lixiviating a few pounds of it, and adding to the liquor thus obtained as much

of a solution of common potash of a known strength, as is sufficient to decompose all the earthy salts. From this assay the quantity of alkali required is easily calculated.

The next process is the lixiviation; which is performed in the following manner. Several cart-loads of nitrous earth are mixed as accurately as possible with the requisite quantity of alkali, either in the form of wood-ashes or pulverized potash. Several large casks with perforated false bottoms are then filled with the prepared earth laid on very lightly; after which as much river water is poured in as the vessels will hold. In two or three hours time the cock at the bottom of each cask is turned, and the liquor is allowed to drain out during the remainder of the day. The casks of a second series charged with earth as before are now filled up with the first lixivium, and after standing for a few hours the liquor thus concentrated is drawn off in the manner just described. By a similar process on the third day a lixivium thrice as strong as the first is obtained, which is now sufficiently concentrated to be boiled down. The contents of each series of casks are lixiviated twice more, and the weak solutions thus obtained are employed instead of water in the first and second lixiviations of fresh parcels of earth.

The boiling down and evaporation next succeeds. The lixivium, containing nitrat of potash, the muriats of potash and soda, with probably a few other salts, and various earthy and other impurities, is put into a large boiler like a salt-pan, and heated nearly to ebullition; it is then clarified by the addition of bullock's blood, or a solution of glue, the impurities as they appear on the surface being carefully skimmed off: when no more froth rises of itself a little lime-water is added, which coagulates the remainder of the blood and glue, and thus compleats the clarification. It is now boiled for several hours, and the muriats of potash and soda as they deposit are withdrawn by a perforated ladle. When the liquor is so concentrated that a few drops crystallize readily on being dropped on a cold iron, it is laded out into a vat, where it remains half an hour to deposit the common salt and impurities still floating in it: hence it is transferred to large wooden or metallic crystallizing basons, where it remains close covered up during from three to six days, according to the temperature of the air; at the expiration of this period the fluid mother water is poured out and returned to the nitre bed, and the salt deposited in a confused crystalline mass of an opake dirty white, is broken to pieces and set to drain, after which it is brought to market or delivered in to the government stores, as rough nitre or nitre of the first boiling.

In order to refine the rough nitre, the ancient practice was to subject it to two more successive boilings and crystallizations; by this method however a very considerable proportion of the nitre was left in the mother waters, no inconsiderable share was volatilized by the heat required for evaporating the solution when it had nearly acquired the due degree of concentration, and besides a great expence both of time and fuel was incurred. The modern method of refining this salt was invented in France a few years ago, and is now considered as brought nearly to perfection. It is thus effected:

The rough nitre is broken to small fragments by wooden mallets, and is then put into a wooden tub with 20 *per cent.* by weight of cold water; in this state it remains for six or seven hours, being occasionally well stirred up, that the water may have free access to every part. The water is now let out by a hole at the bottom of the vessel, and carries with it in solution all the deliquescent salts, and the greatest part of the muriats of soda and potash, together with some nitre. When the whole of the liquor is drained off 10 *per cent.* more of water is added, and well mixed with the nitre for an hour's time, when it is discharged in the same manner as the first. Lastly, 5 *per cent.* of water is poured in and run off again almost immediately after. The nitre thus washed, after being well drained, is put into a boiler with half its weight of water, and boiled till a pellicle forms on its surface; the liquor is then discharged into a large leaden cooler, and stirred about with rakes, till it is quite cold, by which manipulation the salt is deposited in small crystalline needles. It is now taken out of the liquor with a perforated ladle and well drained: after which it is washed with 5 *per cent.* of cold water, and again drained: being then spread out on a large table it dries in a few hours, and is lastly heated over a fire in large basons for two or three hours, at a temperature not exceeding 120° Fahr. taking care to stir it all the while; by this treatment it is perfectly purified and brought to the consistence of fine sand, and is now ready to be manufactured into gunpowder.

NITRAT OF SODA. Cubic or Rhomboidal Nitre.

This salt crystallizes in rhomboids or oblique quadrilateral prisms. Its flavour is similar to

that of common nitre, except that it is somewhat more bitter. It does not appear to occur native, but may readily be prepared by saturating nitric acid with carbonated soda and then evaporating the solution to a pellicle: the crystals are deposited as the liquor cools.

When placed on a hot coal it first slightly decrepitates and is then decomposed like common nitre, only with not so vigorous a detonation. By exposure to the air it becomes soft and moist, without however absolutely deliquiating.

It is soluble by thrice its weight of cold water, and in less than its weight of boiling water. It is decomposed by the sulphuric and other acids with the same phenomena as common nitre; it is also decomposed by potash and barytes, caustic soda being liberated.

It is composed according to Kirwan of

53.21	Nitric acid
40.58	Soda
6.21	Water
100.	

Nitrat of soda is not applied to any use.

Nitrat of Ammonia. *Nitrum Flammans* of the older chemists.

This salt is seldom if ever found native, and is produced in the laboratory by saturating dilute nitric acid by carbonat of ammonia, and evaporating. If the evaporating heat does not exceed 100°, the liquor on cooling shoots into transparent crystals in the shape of six-sided prisms, terminated by long six-sided pyramids. But if evaporated at the heat of boiling water, it yields on cooling thin fibrous crystals, or if the evaporation be carried nearly to dryness, the whole concretes into a compact shapeless mass.

Mr. Davy * infers these three varieties of nitrat of ammonia to be composed as follows: 200 grains of solution of pure ammonia containing 50.5 grains of alkali saturated 385.5 grains of nitric acid of 1306 sp. gr. containing 190 grains of real acid, estimated in the way mentioned under that article. This mixture evaporated at 212° gave 254 grains of fibrous nitrat of ammonia. But from comparing the specific gravity of the mixture before evaporation with that of a solution of another equal portion of the fibrous salt, it was found that 8 grains of the salt were dissipated during the evaporation. The quantity of water in the 254+8 grains of the salt, was 21.5 grains, and hence 100 parts of the fibrous salt are composed of about 72.5 nitric acid, 19.3 ammonia, and 8.2 water.

The prismatic salt (or that produced by gentle evaporation at a heat not exceeding 100°) is composed of about 69.5 *per cent.* of acid, 18.4 of ammonia, and 12.1 of water.

The other variety, the compact salt made by evaporation to dryness at a heat not exceeding 300° contains according to this able chemist 74.5 of acid, 19.8 of alkali, and 5.7 of water. Some of the salt is dissipated during evaporation.

In these three varieties the quantity of alkali bears nearly the same proportion to the acid, and the difference is chiefly in the water of crystallization. During evaporation of the solution at a heat below 100° scarcely any loss of salt is detected; at 212° the loss is about 3 or 4 grains *per cent.* and at the boiling point of the saturated solution (which is many degrees higher) the loss is about 4 to 6 grains *per cent.*

This salt may also be made by the decomposition of sulphat of ammonia by nitre. Nitrat of ammonia and sulphat of potash are formed, and if no more nitre be added than is sufficient for the decomposition, a judicious evaporation and crystallization, two or three times repeated, will separate these two salts almost entirely. Mr. Davy estimates that 100 grains of sulphat of ammonia require about 134 grains of nitre, and yield 91 grains of compact nitrat of ammonia.

This salt is deliquescent in all its forms, and is extremely soluble in water. Its taste is peculiar, and very pungent.

When the dry salt is heated suddenly and strongly (as when a small quantity is dropped on a red-hot earthen crucible) it instantly melts, takes fire and burns with great ebullition and hissing, and a red-blue flame, but without explosion, with nearly the same appearance as when a lump of nitre is thrown on hot coals. Nitrat of ammonia is the only nitrat that deflagrates without the contact of any carbonaceous or inflammable matter, whence the immediate decomposition of the ammonia may be inferred, the hydrogen of the alkali furnishing inflammable matter for the oxygen of the nitric acid. This self-inflaming property makes it necessary to use caution in heating any dry mixture of nitric acid and ammonia in close vessels. It has however been examined in this way by Mr. Davy, and the dry distillation of this salt is now particularly interesting, as it furnishes that curious gas the *nitrous oxyd.*

* Researches.

The compact dry nitrat of ammonia, heated without addition in a ſmall glaſs retort, with the bulb of a thermometer incloſed, was found to undergo little or no change at a heat below 260°. From 275° to 300° it ſlowly ſublimes without decompoſition or without becoming fluid. At 320 it becomes fluid, ſlowly ſublimes, but alſo now begins to be decompoſed and to give out gaſſeous nitrous oxyd. From this the heat may be ſafely raiſed to about 440°, at which it is totally reſolved into the gas, and is diſſipated without leaving any reſidue. The priſmatic and fibrous varieties of this ſalt as they contain more water of cryſtallization, become fluid below 300°, and if not heated above 430°, they part with this water before they are decompoſed into *nitrous oxyd*. The further properties of this gas will be deſcribed under that article.

Nitrat of Barytes.

This ſalt is prepared artificially by diſſolving in dilute nitric acid the native or artificial *carbonat of barytes*, the methods of procuring which are deſcribed under that article.

On evaporating the ſolution and cooling, the nitrat of barytes ſeparates generally in regular octohedrons. This ſalt is of an opake-white, hard, and not deliqueſcent. It is one of the leaſt ſoluble of all the nitrats, requiring twelve times its weight of water at 60°, and about four parts of boiling water. Hence nitric acid poured into a concentrated ſolution of muriat of barytes, will cauſe an immediate white precipitate, which however is reſoluble in more water, and is nitrat of barytes.

This nitrat is compleatly decompoſed by heat, the acid is driven off, and the barytes remains pure and cauſtic, as already mentioned under the article *Barytes*.

Nitrat of Lime.

The production of this ſalt in calcareous buildings, &c. that have been uſed by animals, and its intimate connexion with the manufacture of nitre, has been fully deſcribed under the article *Nitrat of Potaſh*.

Nitrat of lime may be made artificially in great purity by ſaturating nitric acid with white marble or calcareous ſpar. This ſolution when evaporated to a very thick ſyrupy conſiſtence, cryſtallizes in a cool air into long priſms reſembling bundles of needles diverging from a common centre. If further evaporated, the ſolution when cold concretes into a fibrous and ſhapeleſs maſs.

This ſalt is bitter and pungent. It diſſolves in its own weight of boiling water, and twice its weight of cold water. It is very deliqueſcent. When heated *per ſe*, all the water and acid are driven off, and only pure lime remains, but if the heat be too ſtrong it vitrifies with the crucible employed, if of earth. Lime has been ſaid to be cryſtallizable in this way, but the experiment has not ſucceeded with many accurate chemiſts.

Nitrat of Strontian.

This ſalt is readily prepared by ſaturating dilute nitric acid with the native or artificial carbonat of ſtrontian (either of which it readily diſſolves) and evaporating the ſolution, which forms octohedral cryſtals much reſembling the nitrat of barytes in appearance, but much more ſoluble, requiring only five parts of cold water for their ſolution.

This ſalt is alſo compleatly decompoſable by heat, and the ſtrontian is left pure, ſo that it may readily be made to cryſtallize, as will be further mentioned under the article *Strontian*.

Nitrat of ſtrontian like many other ſalts with this baſis give a red flame to burning alcohol.

Nitrat of Magnesia.

This ſalt when cryſtallized aſſumes the form of rhomboidal priſms with obliquely truncated ſummits or of needles for the moſt part adhering to each other. Its ſp. gr. is = 1.73. Its taſte is pungent and bitter like that of nitrated lime. It is ſaid by Fourcroy to occur native and in nitre beds, and to be contained in the mother water of nitre, which is by no means improbable. When wanted however for chemical examination it is prepared by ſaturating nitrous acid with magneſia either pure or carbonated, and then evaporating the ſolution to an oily conſiſtence and ſubſequent cryſtallization.

Nitrat of magneſia when expoſed to the air attracts moiſture, and at length, though ſlowly, is reſolved into a fluid. If heated in a crucible it firſt melts in its water of cryſtallization, and after this has evaporated it becomes dry. On increaſing the temperature it gives out a little oxygen gas, which is preſently ſucceeded by nitrous vapour and nitrous acid, nothing remaining behind except the earth in a ſtate of purity.

This ſalt is ſoluble in its own weight of water at 50° Fahr. and in a conſiderably ſmaller proportion of boiling water; hence it depoſits cryſtals by cooling. It is alſo ſoluble in nine times its weight of alcohol.

When heated with combuſtible ſubſtances it gives out a few ſparks, but cannot, properly ſpeaking, be ſaid to detonate.

Nitrat of magnesia is decomposable with abstraction of its acid by the fixed alkalies; by barytes, strontian, and lime, the magnesia in all these cases being precipitated. Ammonia only in part decomposes this salt, forming with the rest a triple compound, the ammoniaco-magnesian nitrat. The sulphuric, phosphoric, and fluoric acids, with many of their neutral salts, decompose nitrat of magnesia, the earth combining with the added acid. If to a strong solution of this salt, nitrat of lime also in dense solution be added, a precipitation of the magnesian nitrat takes place, being deprived of its water of solution by the nitrat of lime.

Its component parts according to Kirwan are

46	Nitric acid
22	Magnesia
32	Water
100	

It is not made any use of.

Ammoniaco-magnesian Nitrat.

This salt appears in the form of slender acicular prisms: to the taste it is bitter, acrid, and ammoniacal. It is prepared by a partial decomposition of nitrat of ammonia by magnesia, or of nitrated magnesia by ammonia, or, still better, by the direct union of the solutions of nitrat of ammonia and nitrat of magnesia.

By long exposure to the air it attracts a certain quantity of moisture, though it does not deliquiate. It requires eleven times its weight of water at the ordinary temperature for its solution, but a considerably smaller proportion of boiling water; hence this latter solution deposits crystals as it cools.

It is not decomposable by ammonia, but is so by the fixed alkalies and by all the alkaline earths, even magnesia; the ammonia being disengaged. When dropped into a red hot crucible it undergoes a slight inflammation. By exposure to a more gradual heat in a retort it gives out oxygen gas, nitrous vapour, nitric acid, azot and water, the ammonia being entirely decomposed; pure magnesia remains behind.

It is composed according to Fourcroy of

78	Nitrat of magnesia
22	Nitrat of ammonia
100	

It is not made any use of.

Nitrat of Alumine.

This salt is usually of a gelatinous consistence, sometimes though rarely it is obtained in the form of soft thin pliable crystalline plates. To the taste it is sour and astringent, it reddens blue vegetable colours and therefore contains an excess of acid. It has not been found native but may be prepared by digesting pure alumine, or the precipitated earth of alum in nitric acid. In the latter case the earth is dissolved with effervescence on account of a portion of carbonated alkali remaining in it, and this solution for the same reason is more readily crystallizable than when pure alumine is employed. By exposure to the air it soon deliquiates. It is very soluble in water either hot or cold, and by evaporation and cooling generally takes the consistence of jelly. It produces neither flame nor detonation by being heated with combustible bodies. When distilled *per se* the acid flies off at a moderate temperature, leaving the earth behind in a state of purity. It is decomposable by sulphuric and muriatic acids and by all the alkaline bases. It is not made any use of.

Nitrat of { Glycine. See Glycine.
Yttria. See Gadolinite.
Zircon. See Zircon.

Nitrite of Potash, or *Phlogisticated Nitre*.

We have already mentioned that nitrous acid is composed of nitric acid and nitrous vapour. Now if nitrous acid and potash be mixed together the former is decomposed; its nitric acid combines with the alkali forming nitre, while the nitrous vapour assumes a gasseous state and flies off. Hence it appears that no such salt as nitrite of potash can be made by the direct addition of its ingredients. We are indebted however to the sagacity of Bergman and Scheele for the interesting fact that if common nitre be melted *per se* and kept in this state till part of its oxygen is driven off, the residual salt is a proper nitrite of potash. In this state it deliquiates by exposure to the air and is decomposable by the addition of vinegar and any of the stronger acids, red nitrous vapour being given out. Dr. Thomson is of opinion that nitrite of potash differs from the nitrat only in being saturated with nitrous gas: if this be the case the common nitrite ought to contain an excess of alkali.

It is made no use of.

Of the other nitrites nothing is known with any certainty.

NITROUS GAS, or Nitrous Air.

This substance has already been mentioned under the articles *Nitric acid* and *Eudiometry*, (to which we shall refer our readers) and many

of its properties described. It has been there stated to be an *oxyd of azot*, or to consist of azot united with a certain portion of oxygen but not sufficient to constitute nitric acid. On the other hand there is another substance the *nitrous oxyd*, or *gasseous oxyd of azot* also composed of azot and oxygen, but in which the latter is in smaller proportion than in nitrous gas; so that nitrous gas is intermediate between the two, and being readily decomposable by a variety of chemical agents (both those that give and those that take away oxygen) the production of nitrous oxyd or of azot on the one hand, and of nitric acid on the other, is always to be sought for in all experiments on nitrous gas.

The nature of this gas was first explained by Dr. Priestley who shewed it to be a constituent of nitric acid, and shewed *how* it was converted into this acid, that is, by union with oxygen, and hence he ingeniously applied it to the analysis of air containing oxygen, as has been already described under the article *Eudiometry*. Since his time this gas with all its varieties has been the subject of a great number of able researches, and its properties have been very fully explained.

Nitrous gas is obtained most conveniently during the solution of some of the metals in nitric acid. Most of the metals are acted on by this acid and decompose it, but in the process some of them produce nitrous gas nearly pure; others, a mixture of nitrous gas and nitrous oxyd, and others nitrous oxyd nearly pure. The degree of concentration of the acid also and the temperature have a great effect on the gasseous product, for, when these are such as to produce a very violent action, red nitrous vapour is also given out, and the products are different from those that occur with a slower action.

Copper and mercury are the metals that produce the purest nitrous gas. Shreds of copper, or a small quantity of mercury, should be put into a bottle with a curved tube and the bottle nearly filled with an acid of such strength as to act moderately fast at a heat tolerable to the hand, which will be made by diluting the concentrated acid with about three parts of water. As the metal dissolves, the nitrous gas is given out, and after a small quantity has run to waste to displace the air of the vessel, the gas may be collected in jars over water. During the process a gentle heat may be used to hasten the production of gas. By this method nitrous gas may be procured so pure as not to contain more than $\frac{1}{10}$ to $\frac{1}{12}$ of impurity, which is azotic gas. According to Mr. Davy 100 cubic inches of this gas at 56° therm. and 30.9 bar. weigh 34.3 grains, which at 55° therm. and 30 bar. would weigh 34.26 grains.

Nitrous gas therefore is heavier than common air, according to Davy in the proportion of 1101.6 to 1000. 100 inches of common air weighing 31.1 in the same circumstances in which nitrous gas weighs 34.26.

Nitrous gas is to a certain degree absorbable by water. 100 cubic inches of the purest water deprived of the air it naturally contains by long boiling, and cooling over mercury, (that it may not again absorb air from the atmosphere) will absorb about 11.8 of nitrous gas or somewhat more than $\frac{1}{9}$ of its bulk. Common spring water absorbs a smaller quantity, but the absorption however appears less than it really is, as the gas is partly decomposed by the atmospherical air contained in all natural waters, and the azot of this air is given out, whilst its oxygen forms nitric acid with the absorbed nitrous gas. Water saturated with nitrous gas has no distinguishing taste, and if the water be previously boiled and cooled over mercury, it shews no acidity by the most delicate tests. Mr. Davy finds (contrary to the opinion of Humboldt,) that nitrous gas is not in the least altered or decomposed by solution in pure water, and that it is again totally expelled by a boiling heat unaltered.

Nitrous gas is immediately fatal to animals enclosed in it. Mr. Davy had the rashness to inspire a small quantity of it which gave a very burning astringent taste to the mouth and throat (owing no doubt to the formation of nitrous vapour by union with the common air in these organs) and the consequence was severe inflammation which lasted some hours.

This gas dissolves readily in many of the acids. With the sulphuric it gives a purple brown colour, and when in the form of nitrous vapour it causes this acid to crystallize. The change produced in the constitution of *nitric acid* by the absorption of this gas has been fully detailed under this article.

The habitudes of nitrous gas with combustible bodies are peculiar. A taper dipped in this gas is immediately extinguished, but pyrophorus burns with increased flame, as Dr. Priestley discovered. Charcoal is slowly consumed in it if kept at a red heat. The particulars of some of these experiments require a further notice, as they lead to determine the composition of the gas.

[a] Dr. Prieſtley incloſed a piece of charcoal (recently heated ſtrongly in ſand) in nitrous gas and threw on it the rays from a lens for a conſiderable time. The bulk of air was not much diminiſhed, and when examined it was found to contain little or no fixed air, and extinguiſhed a candle.

The ſame experiment was repeated by Mr. Davy. The volume of the gas after the heating of the charcoal for half an hour was increaſed by about $\frac{1}{24}$. On adding a ſolution of pale green ſulphat of iron (which totally abſorbs nitrous gas) a diminution of only $\frac{1}{32}$ of the whole took place, but on throwing up cauſtic alkali a rapid abſorption enſued and the gas was reduced to half its original bulk. Part of the reſidue was mixed with its own bulk of oxygen and the electric ſpark paſſed through, but no effect took place, and hence it was proved to be pure azot. The quantity of the latter therefore was eſtimated to be the whole of the azot contained in the nitrous gas employed, and the proportion of oxygen was inferred from the carbonic acid produced, and which was abſorbed by the alkali, and hence Mr. Davy infers that 100 grains of nitrous gas are compoſed of 56.5 oxygen and 43.5 azot.

But it was poſſible that ſome nitric acid might have been generated by the combuſtion of charcoal in the gas which would eſcape detection in the above mode of analyſing, to determine which the experiment was repeated as before, and ſome pale green ſulphat of iron thrown up to the reſidual gas, after which a few drops of pruſſiat of potaſh were added. Now if any nitric acid had been generated it would have been abſorbed by the ſulphat of iron and reduced a part of it to that ſtate of oxydation in which it gives a *blue* precipitate with the pruſſiat; but the precipitate was ſtill white, and hence it is inferred that no nitric acid was produced.

Pyrophorus was found to burn with eaſe in nitrous gas, and the reſidue was pure azot. From an experiment made with this ſubſtance and an eſtimation of the reſiduary azot, the compoſition of 100 grains of nitrous gas would be 53.4 of oxygen and 46.6 azot. But the decompoſition by charcoal appears the moſt correct, ſo that on the whole it may be eſtimated that 100 grains of this ſubſtance contain 56 of oxygen and 44 of azot.

Some combuſtible ſubſtances burn in nitrous gas if actually in vivid combuſtion when they are introduced, but cannot be brought to this ſtate when heated in the gas. Phoſphorus is an example of this, as it may be fuſed and even ſublimed in nitrous gas without change, but when already inflamed it continues to burn in the gas with nearly as much vividneſs as in oxygen.

Burning ſulphur however is inſtantly extinguiſhed in nitrous gas.

The electric ſpark when taken repeatedly in nitrous gas over water, diminiſhes it to one fourth of its original quantity,[b] at the ſame time that nitric acid is produced, litmus encloſed in it being ſtrongly reddened. If the electrization be carried on in contact with mercury the diminution is only one half; and a white powder is obtained which is the nitrat of this metal. The air remaining after the utmoſt effect of the electric ſpark appears to be pure azot. This decompoſition is much more rapid than the formation of nitric acid by the electrization of common air or any mixture of ſimple oxygen and azot.

In this proceſs Berthollet conjectures that nothing is added or taken away by the ſurrounding bodies, but that the whole change takes place in the nitrous gas itſelf by the condenſation of its oxygen into one portion of the azot to form the nitric acid, and its conſequent deſertion of the other portion. Neither inflammation nor detonation is produced by paſſing a ſtrong ſhock through a mixture of hydrogen and nitrous gas.

Mere heat does not produce any ſenſible change on this gas.

Much has already been mentioned under the article *Eudiometry* concerning the abſorption of nitrous gas by a ſolution of ſulphat of iron, (firſt noticed by Dr. Prieſtley) and the very elaborate inveſtigation of this difficult ſubject by Humboldt and Vauquelin, together with ſome of the objections brought by Berthollet on the ſource of the ammonia formed in this proceſs. Others of equal force have been urged by Mr. Davy, to whoſe experiments on this ſubject we muſt refer the reader. From them he concludes that the *red* or fully oxygenated ſulphat of iron has little or no affinity with nitrous gas, and that the common green vitriol abſorbs nitrous gas only in proportion to the quantity of ſuboxygenated or *green* ſulphat which it contains, (for an account of the difference between theſe two [illegible] ſee the article *Iron*) and that at a common temperature the nitrous gas is ſimply diſſolved therein without being decompoſed.

A highly concentrated ſolution of green ſulphat will diſſolve about 12 times its bulk of nitrous gas.

[a] Experiments on Air, Vol. II. p. 89.

[b] Prieſtley.

The ſame difference as exiſts between the red and green ſulphat of iron is found in the red and pale muriat of iron and ſimilar habitudes with nitrous gas; for the red muriat has very little action on this gas, but the pale muriat abſorbs it with ſtill more eagerneſs than the pale ſulphat. This muriat is formed by diſſolving iron filings in muriatic acid, taking care to keep a quantity of undiſſolved metal in the ſolution, and preſerving it in a cloſely corked bottle. This ſolution is of a pale green colour, and gives a white precipitate with pruſſiat of potaſh. One cubic inch of the ſolution highly concentrated will abſorb nearly 24 inches of pure nitrous gas, which changes the colour to a very dark brown but produces no precipitate. The ſolution of the green muriat or ſulphat before it is employed to abſorb nitrous gas for eudiometrical purpoſes, ſhould be boiled for a few minutes to expel the ſulphuretted hydrogen which it may contain.

The other facts known relating to its decompoſition will be mentioned in the following article of *nitrous oxyd*, which as it contains leſs oxygen than nitrous gas, is produced by the action of deoxygenating ſubſtances on nitrous gas.

NITROUS GAS ETHERIZED is a peculiar inflammable gas formed by the mutual action of nitric acid and alcohol. See *Ether nitrous*.

NITROUS OXYD, or *Gaſſeous oxyd of azot. Dephlogiſticated nitrous air* of Dr. Prieſtley.

This gas was firſt diſcovered by Dr. Prieſtley by expoſing iron to nitrous gas; he has alſo given a number of curious experiments on the mode of its formation and has detailed a great number of its phyſical and chemical properties. From the circumſtance of its ſupporting combuſtion in an eminent degree (in many inſtances almoſt equal to oxygen gas in this reſpect) and being produced by the decompoſition of nitrous gas, Dr. Prieſtley gave it the name of *dephlogiſticated nitrous air*, but as this term is founded on the doubtful theory of phlogiſton, and as it might lead to the miſtake of ſuppoſing that this gas really contained more oxygen than nitrous gas, Mr. Davy's appellation of *nitrous oxyd* is much to be preferred.

Since the experiments of Dr. Prieſtley this ſubſtance has been the ſubject of very careful reſearch by the Dutch chemiſts, and other philoſophers, and in particular by Mr. Davy whoſe excellent memoir on nitrous oxyd has almoſt ſupplied every thing that the great diſcoverer had left to his ſucceſſors.

Nitrous oxyd is a ſubſtance compoſed, like nitrous gas, of azot and oxygen, but in which the oxygen is in a ſmaller proportion, ſo that in this reſpect it holds an intermediate place between nitrous gas and atmoſpheric air, which laſt is the leaſt oxygenated of all the ſimple natural combinations of theſe two elements. However, though nitrous oxyd contains leſs oxygen than nitrous gas, the mode of combination appears to differ conſiderably and much to influence its power of containing combuſtion and other chemical properties.

The diſtinguiſhing properties of nitrous oxyd are the following: it is readily abſorbed by water to about half the bulk of this fluid, and the ſolution has a ſweetiſh taſte, but it is not in the leaſt degree acid: a candle burns in it with an enlarged flame and crackling noiſe: phoſphorus actually ignited burns in it with nearly as much brilliance as in oxygen gas: ſulphur when burning in the common way with a feeble blue flame is immediately extinguiſhed in the gas, but when burning vehemently before introduction, the combuſtion continues with increaſed rapidity: ignited charcoal burns in it nearly as in oxygen gas: neither oxygen nor nitrous gas have any ſenſible effect on it at a common temperature: animals incloſed in the gas ſoon die, but it may be breathed when mixed with common air. Other properties of this gas will preſently be mentioned, but the action of water, of combuſtible bodies, and the inaction of oxygen and nitrous gas, will ſufficiently diſtinguiſh it.

Therefore in the decompoſitions of nitrous gas the quantity of nitrous oxyd produced may be found by agitating the reſidual gas in water. But if any unaltered nitrous gas remain (which is very commonly the caſe, and is ſhewn by the diminution and red fumes with oxygen gas) it muſt be previouſly abſorbed by ſulphat or muriat of iron, which has no effect on nitrous oxyd, after which the nitrous oxyd may be abſorbed by water, and the remaining gas is pure azot.

Nitrous oxyd has never been found native nor has it been detected in any of the proceſſes of nature. It is produced artificially in ſeveral ways, namely:

1ſt. From the decompoſition of nitrous gas by thoſe ſubſtances which abſorb its oxygen.

2dly. From the action of nitric acid on many of the metals under particular circumſtances.

3dly. From the decompoſition of nitrat of ammonia by ſimple diſtillation.

Each of theſe methods ſhall be diſtinctly noticed.

The ſubſtances that abſorb oxygen from nitrous gas are many of them thoſe that abſorb

oxygen from common air, so that the same experiments which succeed in common eudiometric processes will often convert nitrous gas into nitrous oxyd.

The sulphite of potash effects this change with greater rapidity than any other substance. Mr. Davy found that at temperature 46°, 16 cubic inches of nitrous gas were converted in less than an hour into 7.8 inches of nitrous oxyd by about 100 grains of pulverized sulphite of potash, retaining its water of crystallization. This appears to act by the simplest possible affinity, namely that of the sulphite for that part of the oxygen which makes the difference between nitrous gas and nitrous oxyd. The azot with which nitrous gas is always mixed remains unaltered.

Nitrous gas exposed to dry muriat of tin is slowly converted into nitrous oxyd, apparently by the same simple affinity as by the sulphites.

All the dry sulphurets produce the same change on nitrous gas in about the same time that they would require to deoxygenate common air.

Iron filings and sulphur mingled together and moistened produce the same effect on nitrous air, and the change is effected in about twelve hours.

Iron filings alone produce the same change, which was Dr. Priestley's first experiment by which he discovered this gas.

The presence of moisture has been supposed necessary to the success of the experiment, but this does not seem to have been the case. Dr. Priestley filled a half pint phial with nails and then with quicksilver, after which the latter was displaced by nitrous gas, and the phial was left with its mouth standing over mercury.

No moisture was intentionally introduced here, but in the course of two months the gas was converted into nitrous oxyd. Dr. Priestley however adds that when the process is carried on over water the change is effected in a few days.

When dry nitrous gas and dry sulphuretted hydrogen are mixed together over mercury a mutual decomposition slowly takes place.[c] The gasses are diminished, sulphur is deposited, nitrous oxyd is formed, and signs of the production of ammonia and water are perceived.

As the sulphur is deposited in this experiment, and no sulphuric acid produced, the hydrogen must be the sole deoxygenating agent, but as some ammonia is produced, a portion of the azot of the nitrous gas must also be separated to contribute to the formation of the alkali. A part of the hydrogen therefore appears to unite with the excess of oxygen of the nitrous gas and forms water, and another part of it with a portion of the azot of the nitrous gas forms the ammonia. But the removal of this azot from the nitrous gas would have a direct effect in preventing its conversion into nitrous oxyd, and therefore the abstraction of its oxygen must be greater in this than in the simple decompositions of nitrous gas, and the entire quantity of nitrous oxyd produced should be less. There is too much variation however in the different experiments to allow of much accuracy of results with these complicated agents.

Zinc filings convert nitrous gas into nitrous oxyd with as much ease as iron filings, but only when in contact with water. Ammonia is produced and the zinc is changed to a white oxyd, which can only be explained by the supposition of a double decomposition of the water and the nitrous gas, the latter yielding part of its azot to part of the hydrogen of the water for the ammonia; part of its oxygen to the remainder of the hydrogen in order to produce the change from nitrous gas to nitrous oxyd; and the oxygen arising from the decomposed water uniting with the zinc.

Another method of producing nitrous oxyd has been stated to be during the solution of several of the metals in nitric acid under particular circumstances of concentration, heat, &c. The gas in this case is always mixed with nitrous gas, and often with azot. The metals from which it is produced with the greatest ease are iron, zinc, and tin. Iron produces a variable mixture of nitrous gas and nitrous oxyd. If a cold saturated solution of nitrat of iron is heated, much nitrous oxyd is produced.[d] A great quantity of it is also given out by adding iron filings to nitrat of iron, and the filings pass to the state of black oxyd, as Berthollet has observed. When tin is dissolved in concentrated acid of about 1.4 sp. gr. (which is nearly as strong as is able to act on this metal) the gas is a mixture of about one part of nitrous oxyd with two of nitrous gas, and a very small quantity of azot. With an acid of 1.24 the proportion of nitrous oxyd is greater, and increases to about $\frac{1}{4}$ of the whole towards the end of the process.[e]

Zinc also yields this gas during the action of nitrous acid of any specific gravity, and in most abundance when the acid is dilute, and towards the middle and end of the process. The nitrat of zinc whilst distilling to dryness gives much

[c] Davy. [d] Priestley. [e] Priestley and Davy.

of the nitrous oxyd. From 100 grains of zinc during their solution in 300 grains of nitric acid of 1.43 diluted with 14 times its weight of water, Mr. Davy obtained 26 cubic inches of gas, of which $\frac{7}{36}$ were nitrous gas, $\frac{17}{36}$ nitrous oxyd, and the remainder azot.

It is to be observed that ammonia is known to be produced in very sensible quantities during the solution of these three metals in nitric acid, and the production of this alkali seems to be intimately connected with the evolution of nitrous oxyd, as has been already explained.

The third method of producing nitrous oxyd has been stated to be by the distillation of *nitrat of ammonia*. This has been already mentioned generally under that article, but as this is the most economical, and altogether the best method of preparing the gas for chemical purposes and that which is actually used in the laboratory, the following directions of a very able and practical chemist may be useful.[f] "Introduce into a glass retort some pure nitrat "of ammonia, and apply the heat of an "Argand's lamp; the salt will soon liquefy, "and when it begins to boil gas will be evol-"ved. Increase the heat gradually till the "body and neck of the retort become filled "with a transparent milky white vapour. In "this state the temperature of the fused nitrat "is between 340° and 480°. After the decom-"position has proceeded for a few minutes, so "that the gas evolved quickly enlarges the "flame of a taper held near the orifice of the "retort, it may be collected over water, care "being taken during the whole process never "to suffer the temperature of the fused nitrat "to rise above 500°, which may easily be "judged of from the density of the vapours in "the retort, and from the quiet ebullition of "the fused nitrat, for if the heat be increased "beyond this point the vapours acquire a red-"dish and more transparent appearance, and "the fused nitrat begins to rise and occupy "twice the bulk it did before. The nitrous "oxyd after its generation is allowed to stand "over water for at least six hours, and is then "fit for respiration and other experiments."

It may be added that as there is always some loss of the gas from absorption by the water over which it stands, the same water may be used repeatedly.

Having thus given the general methods of procuring this gas, we proceed to describe its chemical properties more particularly.

Dr. Priestley found that water readily absorbed about half its bulk of this gas, which is again expelled unaltered. Mr. Davy found nearly the same; the utmost absorption by water thoroughly purged of air by boiling, and cooling under mercury being 54 cubic inches of gas to 100 of water. Consequently 25300 grs. (the weight of 100 cubic inches of water) will absorb 27 grains of the gas. The aqueous solution is sensibly sweet to the taste, but shews no marks of acidity. The gas is again expelled from the water by heat unaltered. When the saturated water is shaken with carbonic acid and sulphuretted hydrogen these are absorbed, and the nitrous oxyd expelled unchanged: but on the other hand, the oxyd expels most of the other gasses from water and takes their place in the solution.

Ether and alcohol and the essential oils absorb this gas in larger quantity than water, but apparently produce no change in its chemical constitution.

The concentrated sulphuric and nitric acids neither absorb nor alter it: the weaker acids simply absorb it.

Neither the green muriat nor green sulphat of iron, nor muriat of tin, nor any of the common deoxygenating liquid substances appear to have any effect on this gas at common temperatures. The same may be observed of gasseous bodies, such as nitrous gas and sulphuretted hydrogen. Neither is there any alteration produced on nitrous oxyd by the substances which impart oxygen. Even oxymuriatic gas the most powerful oxygenating agent mingles with nitrous oxyd unaltered.

None of the alkalies either pure or carbonated, solid or in solution, have any effect on this gas when presented to them *ready formed*, but if the alkalies are brought in contact with nitrous oxyd in its *nascent state*, a singular combination is formed.[g] The method of making this species of neutral salt with potash, is to mix sulphite of potash with a little caustic potash (retaining the water of crystallization) and inclose it in an atmosphere of nitrous gas. The sulphite first acts on the nitrous gas, converting it to nitrous oxyd, as already described, (itself changing thereby to sulphat of potash) and the nitrous oxyd in the moment of formation is absorbed by the free alkali, and forms this singular combination. When the process is finished the saline mass consists of sulphat of potash, probably with some undecomposed sul-

[f] Accum's System of Chemistry. [g] Davy.

phite, of the combination of nitrous oxyd with potash, and generally of some unsaturated potash and carbonat of potash. By solution in water and crystallization, the sulphat and sulphite of potash may be separated, these being much less soluble in water than the other salt, but there is no means of separating entirely the carbonat of potash.

The salt of nitrous oxyd and potash is readily soluble in water, has a caustic pungent taste, and does not part with the nitrous oxyd by boiling. But if any acid is added, a brisk effervescence takes place, and the oxyd is given off pure unless the salt contained also an alkaline carbonat, in which case the gas is mixed with carbonic acid. Carbonic acid gas thrown into a solution of the salt expells the nitrous oxyd, so that the affinity of the latter for alkalies is weaker than that of the weakest acid. From a rough estimate Mr. Davy conjectures that this salt consists of about 3 parts of alkali and 1 of nitrous oxyd by weight.

A similar salt may be formed with soda by the same methods, employing the sulphite of soda and caustic soda, but the ready solubility of sulphat of soda would render it more difficult to procure the nitrous oxyd salt separate.

The phenomena that attend the combustion of different bodies in this gas are highly interesting as they afford the only means of decomposing this substance, and of determining the nature and proportion of its constituent parts.

Dr. Priestley first observed that when a lighted taper was let down into a jar of this gas it burned with an increased flame, and a crackling noise similar to the combustion in oxygen gas, but there is this essential difference between the two gasses (as far as relates to their power of supporting combustion) which is, that when a substance previously ignited in any degree in the open air is introduced into oxygen gas, the combustion instantly increases and is raised to intense vehemence; whereas, in nitrous oxyd bodies previously ignited only to a low degree are immediately extinguished, and it is only when already in *strong* ignition or by the application of a strong heat to them after inclosure in this gas, that the combustion goes on at all, and then rises to a greater intensity than in common air. Thus if phosphorus is inclosed in nitrous oxyd and touched with an iron heated to a low redness, the phosphorus melts, and may even be sublimed unaltered, but if touched with an iron heated white hot, a violent detonation takes place. Much caution is required in performing this experiment. If the phosphorus be previously warmed or sublimed in the gas, a violent detonation cannot be avoided when the heat is afterwards raised to ignition, on account of the vessel being already full of phosphoric vapour, but to make this substance burn quietly and vividly in nitrous oxyd as it does in oxygen, it should be previously set fire to and suddenly introduced into the nitrous oxyd.

Phosphorized hydrogen gas and nitrous oxyd mixed together may be fired with the electric spark.

Sulphur when introduced cold into the gas cannot be fired by applying an iron wire even white hot, and it may be fused and sublimed in the gas without alteration. Even when it is previously kindled, if only burning weakly with a faint blue flame, it is immediately extinguished in the gas. But if it is in strong ignition and then introduced in the gas it burns vividly, with a rose-coloured flame. In this experiment and that with phosphorus, Mr. Davy succeeded by introducing into the jar containing the nitrous oxyd, the phosphorus or sulphur in a small tube containing oxygen, balanced so as to swim on the surface of the mercury without communicating with nitrous oxyd. The phosphorus or sulphur was fired in the oxygen by an ignited iron wire, by which at the moment of combustion the tube containing it was raised into the nitrous oxyd, and thus the inflammation continued. The combustion with sulphur however will succeed in the following manner:[h] Dip a slip of copper into melted sulphur; when cold set fire to it, and when in strong combustion introduce it into a jar containing the gas, when it will continue to burn with a beautiful rose-coloured flame.

Iron wire, charcoal, pyrophorus, and many other combustible substances, may be burned in the nitrous oxyd by similar means.

In all these combustions the oxygen necessary to this process must be furnished by the nitrous oxyd, consequently this gas must either be totally decomposed, or converted into a compound in which the oxygen is in a less proportion than before; in the former case the residue after combustion will be mere azotic gas, (that is, in case no new gas is generated by the act of combustion) and in the latter it will be a compound considerably resembling atmospheric air in constitution. Hence too it appears probable that the state of oxygenation of azot which constitutes atmospheric air, is a precise

[h] Accum.

point or mode of combination of azot at which the deoxygenation of nitrous oxyd would have a tendency to ſtop, as nitrous oxyd itſelf is with regard to nitrous gas; and nitrous gas with regard to nitric acid.

Two more decompoſitions of nitrous oxyd require to be noticed, that by the electric ſpark ſimply, and that by hydrogen aſſiſted by the electric ſpark.

Dr. Prieſtley found that on taking the electric ſpark frequently in nitrous oxyd, no perceptible change was produced in its quantity, but it was become immiſcible with water.

The ſame experiment was repeated by Mr. Davy with accuracy, and by paſſing 150 ſtrong ſtrokes through 7 ten-grain meaſures of pure nitrous oxyd, after which it was reduced to 6 meaſures. This reſidue mixed with 6 meaſures of nitrous gas and a little water, gave red fumes, and a diminution of bulk took place nearly equal to that which common air would produce with nitrous gas. In another experiment the ſame quantity of nitrous oxyd was reduced to 6¼ meaſures, and red cabbage juice ſaturated with nitrous oxyd, and rendered green by alkali, had its red colour reſtored in the proceſs, thus ſhewing the production of an acid, which could be no other than the nitric. The effect of electrization therefore is entirely to decompoſe the nitrous oxyd, to condenſe a larger proportion of the oxygen into one portion of the azot and convert it into nitrous acid, and conſequently to leave a ſmaller proportion of oxygen in the remainder, and thus produce the gas reſembling atmoſpheric air.

A ſimilar change is produced by tranſmitting nitrous oxyd through a red hot glazed porcelain tube.

When hydrogen and nitrous oxyd are mixed and the electric ſpark paſſed through, they explode with conſiderable violence, and with a bright red light. The bulk of the reſidue is always much leſs than the united bulk of the gaſſes before the exploſion, but the exact quantity (the gaſſes being pure) depends on the proportion in which the two are mixed. The nature of the reſidue alſo varies according to the proportion of the gaſſes: where the hydrogen is to the nitrous gas as 50 to 40, the decompoſition is perfect, the reſidue is entirely azot, about a fourth more in bulk than the nitrous oxyd, and conſequently is not changed by nitrous gas nor abſorbed by water. As all the hydrogen diſappears, it muſt unite with the oxygen of the nitrous oxyd to form water, and no traces of nitric acid can be perceived. Where the hydrogen is leſs in quantity than the nitrous oxyd, the effect ſeems to be that of the former inſtance combined with that produced by the ſimple electrization of the nitrous oxyd, ſo that the products are, water, azot, nitric acid, and a mixture of azot and oxygen.

The decompoſition of nitrous oxyd by charcoal, hydrogen, and phoſphuretted hydrogen, were all found by Mr. Davy's experiments to offer a very ſatisfactory agreement in the reſults, conſidering the difficulty of analyſis. The ſmalleſt quantity of oxygen found in the gas was 35 in 100, by weight, and the largeſt 39. If the mean between the two is taken, it may be concluded that 100 grains of it are compoſed of about 63 of azot and 37 oxygen; and that 100 cubic inches weigh 50 grs. at 55° temperature, and 30 inches of atmoſpheric preſſure.

We may conclude this article with the table of the combinations of azot given by Mr. Davy, which may be conſidered on the whole as the neareſt approximations to accuracy which we poſſeſs.

100 cubic inches at 55° Therm. and 30 Bar.

		grains
Of azot - - - - - -	weigh	30.04
Oxygen - - - - - - -		35.06
Atmoſpheric air - - -		31.10
Nitrous oxyd - - - -		50.20
Nitrous gas - - - - -		34.26
Gaſſeous nitric acid - -		76.00

Compoſition of 100 grains of the above ſubſtances.

	Azot	Oxygen
Atmoſpheric air - -	73.00	27.00
Nitrous oxyd - - -	63.30	36.70
Nitrous gas - - -	44.05	55.95
Nitric acid - - - -	29.50	70.50

O

OBSIDIAN. Iceland Agate.

Its usual colour is pure black, whence it passes into greenish and greyish-black, blackish, bluish, and greenish-grey, and smoke-grey. It occurs in mass, and in rough, roundish, detached pieces. Internally its lustre is more or less shining and vitreous. Its fracture is perfect and large conchoidal. Its fragments are indeterminately angular and very sharp-edged. It is more or less transparent on the edges. It is hard, but easily frangible. Sp. gr. 2.34. Before the blow-pipe it melts without addition into a greyish-white opake somewhat porous enamel. The Obsidian of Iceland has been decomposed by Bergman, and more recently by Abildgaard, with the following results:

Berg.		Abild.	
69	—	74	Silex
22	—	2	Alumine
9	—	14	Oxyd of iron
100		90	

The hardness and opake blackness of this mineral added to the high polish of which it is capable, have caused it to be employed for various kinds of ornaments. In Peru at the time of its conquest by the Spaniards, it was used for mirrors, and has been fashioned in Europe into reflectors for telescopes.

It occurs in large beds in the Lipari islands, near Sicily, where it evidently passes into pumice: it is met with near Tokay in Hungary, in smoke-coloured nodules in decomposing granite and porphyry (these nodules sometimes go by the name of *Lux sapphire*). It abounds in Iceland, not only in the vicinity of Hecla but elsewere; also in the island Melos in the Archipelago; near Grantola in the north of Italy: in the island of Madagascar, in Peru and Siberia.

It is one of the minerals whose origin is warmly contested by the Neptunians and Volcanists, many of the latter denominating it vitreous lava.

OIL. Huile. *Fr.* Oehle. *Germ.*

Various substances are included under the general appellation oil, which however differ so essentially in many particulars from each other, as to render it impossible to comprehend them under any proper specific definition: we have therefore divided this class of bodies among the four following articles.

Oils Vegetable Unctuous.

Unctuous or fixed vegetable oil occurs principally in the cotyledons of certain seeds, and sometimes though rarely in the pulp or flesh of fruits. In the former it is always mixed with a greater or smaller proportion of fecula and mucilage, on which account these seeds when rubbed in a mortar with cold water, form with it a white opake milk-like fluid called an *emulsion*; from which by long standing (or more speedily by the addition of an acid) the oil separates, rising to the surface in the form of a thick cream.

There are two ways of extracting oil: the first and most usual is by means of pressure; the second is by immersion in hot water; in this latter case the oil separates from the other ingredients with which it is naturally mixed, and rises by the force of gravity to the surface of the water, from which it is skimmed off.

Recently drawn oil however is more or less impure on account of its containing a variable proportion of mucilage, fecula, and perhaps other substances: of these a part is always deposited by rest, especially if the contact of the air is not entirely excluded; but another portion remains in permanent solution, and to this that partial spontaneous decomposition in oils called *rancidity* is principally owing.

Fixed oil at the common atmospherical temperature is usually in the state of a moderately thick, but not, properly speaking, viscid fluid; to the touch it is remarkably smooth and unctuous; it has a mild sub-nauseous taste, and a peculiar flavour, according to the vegetable from which it is procured. Its colour when recent has more or less of a greenish tinge, which by keeping becomes yellow, and in some instances orange-coloured, verging on red. Its specific gravity is usually between that of alcohol and of water, hence it sinks in the former and floats on the surface of the latter of these fluids. There is nothing in which oils differ from each other so much, as in the temperature at which they congeal; some continue solid at the highest atmospherical temperature, as palm oil, and the rest of the vegetable *butters* (as they are called from this very circumstance) others require being cooled down to the freezing point of water, and others again are capable of enduring a much greater cold without solidifying.

Water seems to be incapable of combining

with fixed oil in any proportion: if the two fluids are ſtrongly ſhaken together in a half-filled vial, the oil is broken into very minute globules, and thus gives the water the appearance of thin milk or whey, but after ſtanding for a few ſeconds the whole of the oil riſes to the ſurface, and the two liquors remain as clear and diſtinct as at firſt. That a conſiderable attraction ſubſiſts between water and oil is however manifeſt from the well-known fact, that if a drop of oil be let fall into a baſon of water, it does not retain its globular form, but immediately ſpreads itſelf into a thin irideſcent film with which the whole ſurface of the water is covered.

The fixed oils are ſo called becauſe they are incapable of being volatilized by heat without decompoſition: when therefore any of them, olive oil for example, is heated in a cloſe diſtillatory apparatus, as ſoon as the fluid has arrived at its boiling point a white vapour is diſengaged, conſiſting of oil, carburetted hydrogen, and carbonic acid; of theſe the firſt is for the moſt part condenſed in the receiver, while the other two, holding a portion of oil in ſolution, eſcape in the form of permanent gas; when every thing volatile has been driven off, nothing remains in the retort but a little charcoal. The oil which is found in the receiver is lighter, more limpid and volatile than that from which it was procured, and theſe qualities are obſerved to increaſe by each ſucceſſive diſtillation, carbon and carburetted hydrogen being diſengaged as at firſt. By treating in this manner the product of each diſtillation the oil at length entirely diſappears, being partly decompoſed and partly carried off in ſolution by the carburetted hydrogen gas.

If oil inſtead of being diſtilled is heated in an open kettle, its colour by degrees becomes deeper, a highly inflammable and fetid vapour eſcapes, and the remaining oil is found to be thick, viſcid, and when ſpread over wood or any other ſubſtance and expoſed to the air, congeals into a ſolid, tough, tranſparent varniſh. In this ſtate it is called boiled or *drying* oil. It has not been very ſatisfactorily ſhewn what takes place on this occaſion, but it is probable that the mucilage and fecula are for the moſt part charred and decompoſed, that the water with which they were combined is volatilized, that a ſmall portion of the oil itſelf is driven off, and that the reſidue has abſorbed ſome oxygen from the air. When oil is expoſed to a high heat and at the ſame time to the free contact of the atmoſphere it takes fire, and burns with a copious flame, accompanied by a thick black ſmoke; the combuſtion of oil however does not readily take place except by means of a wick: if an Argand lamp is uſed for this purpoſe the flame is of a pure white colour, and no ſmoke is produced, the whole of the oil undergoing entire combuſtion. In this proceſs the oil, according to Lavoiſier, is converted into water and carbonic acid, in ſuch proportions, that its conſtituent parts may be ſtated at 21 of hydrogen, and 79 of carbon. In this however no allowance is made for the oxygen which oil no doubt contains, ſo that at beſt the given proportions can be looked upon only as a looſe approximation to the truth.

It is known that ſome of the fixed oils (and probably all of them) abſorb oxygen, either from the air or from oxygen gas, at the common temperature. Berthollet diſcovered that oil of almonds in a jar half filled with oxygen gas ſtanding over water, had in the courſe of a month abſorbed nearly the whole of the oxygen, and at the ſame time depoſited a number of white concretions forming a thin ſtratum between the water and the oil. In another experiment this able chemiſt expoſed a very thin ſtratum of oil on the ſurface of water to the contact of atmoſpheric air for three months: at the end of this period the oil was found converted into a white concrete ſubſtance, friable at a low temperature, but fuſible at a leſs heat than that required for the melting of wax.* By long expoſure to the air ſome oils, as olive oil, become rancid, in which ſtate they exhibit the following characters: the colour is deepened, the odour becomes ſtrong and diſagreeable, the conſiſtence is viſcous or ropy, and vegetable blues are changed to red, ſhewing the developement of an acid. Other oils on the contrary in ſimilar circumſtances only dry to a tough varniſh. The former are often called *fat oils*, and the other ſpontaneouſly *drying oils*.

Of the ſimple combuſtibles, hydrogen in the ſtate of gas is ſlowly and ſparingly taken up by oil, but the effect of this combination has not been examined. Charcoal appears to be wholly inſoluble in oil, but when newly burnt it has the property of bleaching and purifying it to a conſiderable degree.

Phoſphorus by the aſſiſtance of heat is ſoluble in oils though ſparingly, and the compound has the property of becoming luminous if ſmeared thin over any dry ſubſtance and expoſed to a warm air. A few drops of the phoſphorized oil if rubbed on the hands or

* Mem. de l'Acad. 1795. p. 329.

face, cause them to shine in the dark without any risk of injury from the slow combustion of this highly inflammable substance. If the oil has been charged with phosphorus at a boiling heat, a portion of this latter deposits by cooling in octohedral crystals. Phosphorized oil when distilled affords phosphuretted hydrogen gas.

Sulphur is easily and largely soluble in boiling oil: the compound has a thick somewhat viscid consistence, and a deep red colour, hence it was formerly named *ruby of sulphur*. When highly charged with sulphur at a boiling heat, it deposits a part by cooling: if this takes place rapidly the sulphur is in the form of needles, if more slowly it forms octohedral crystals.

Sulphurized oil has a strong fetid odour, and when distilled gives out a large quantity of sulphuretted hydrogen.

Most metallic oxyds are decomposed by the fixed oils at a boiling heat: those however that are commonly employed for this purpose are minium and litharge. If either of these substances ground to a very fine powder, be put in a kettle with a little water and some *fat* oil, and the whole be well mingled by constant stirring, it will be found that the oil when nearly at the temperature of boiling water, first abstracts part of the oxygen from the oxyd, and then dissolves pretty rapidly the oxyd itself. In consequence of this the oil becomes thick and coloured, acquires a peculiar odour, and when cooled becomes opake, and of a soft pasty consistence. By continuing the heat after the solution of the oxyd, till the water is compleatly driven off, the residue on cooling acquires nearly the consistence of wax, and is known in pharmacy by the appellation of *plaster*. If instead of fat oil, *drying* oil be made use of, the mixture cannot be made harder than stiff paste. Deyeux[b] has shewn that the fat oils when previously mixed with mucilage, are exactly similar in this respect to the drying oils. Plaster is not soluble either in alcohol or water, in which respect it differs materially from the proper soaps, to which it has been compared by some chemists. If after the oil and litharge have combined together the water is poured off, instead of being dissipated by a further continuation of the heat, and then evaporated considerably in a separate vessel, it will be found to have acquired a thick syrupy consistence and a saccharine taste. The discovery of this peculiar sweet matter is due to Scheele, from whose experiments on the subject the following particulars are extracted.[c]

It is neither crystallizable nor susceptible of fermentation: if prepared with perfectly fresh oil it appears to contain no lead, but if rancid oil has been made use of, it yields a precipitate of sulphated lead with sulphuric acid. If after being inspissated it is strongly heated, the vapours that arise will take fire on the application of a candle. By destructive distillation repeated two or three times at a temperature equal to that required for the volatilization of sulphuric acid, it is decomposed into brown empyreumatic oil, and a light spungy coal, carburetted hydrogen being probably given off at the same time. By repeated abstraction with nitric acid it is at length converted into oxalic acid.

If the naturally drying oils are boiled upon a small quantity of litharge without the intervention of water, they become thick and glutinous, and more drying than before. Not only the oxyds, but also aqueous solutions of the acetite of lead, as well as the sulphat of zinc, are employed for this purpose.

The alkalies, both fixed and volatile, and the alkaline earths when perfectly caustic, act with energy upon all the fixed oils, but more especially on the fat ones, forming with them Soaps of various qualities; for an account of which the reader is referred to that article.

The action of the stronger acids upon oils is very remarkable, on which account we shall treat of it with some minuteness.

The compound produced by the mutual action of fixed oil and sulphuric acid, improperly called an acid soap, has been examined by Achard[d] with the following results. To prepare this compound, put 7 parts of concentrated sulphuric acid into a porcelain mortar, and add drop by drop 8 parts of oil heated nearly to ebullition, taking care to stir the whole constantly during the process: if the oil is added too quickly an effervescence takes place accompanied by the suffocating odour of sulphureous acid, but this must be carefully avoided. The compound when recently prepared is of a black colour, and nearly of the consistence of thick tar, but by washing thoroughly in 6 parts of distilled water the oil assumes nearly the appearance of brown wax: if it is still acidulous to the taste, repeat the washing in successive small quantities of water, till the last no longer exhibits any signs of uncombined acid. The oil becomes considerably heavier by this treatment, not unfrequently sinking in water: it is solid and brittle, has a peculiar odour, is perfectly soluble in alcohol, and with water makes an opalescent

[b] Ann. de Chem. xxxiii. p. 59. [c] Ess. p. 364. [d] Journ. de Phys. xvi. p. 411.

mixture, which lathers like an infusion of common soap. The watery solution exhibits the following phenomena. With semi-caustic potash it yields an opake coagulum, and being then moderately heated the oil melts into one mass, which on cooling concretes into a brown waxy matter, entirely separate from the aqueous fluid, from which crystals of sulphated potash are deposited by evaporation. Caustic ammonia produces no visible change at first, but in a short time causes the separation of a coagulum that is resoluble in an excess of alkali, but if washed and melted, exactly resembles the precipitate by potash. Both magnesia and chalk produce a similar coagulation of the oily part of the solution. A like decomposition takes place by digestion with ceruse, with filings of iron or of zinc, with the acetites of lead and copper, with nitric, muriatic, and strong acetous acids, with nitrat of potash and muriat of ammonia, but not with nitrat of soda, or muriat of soda. The coagulum in all these cases assumes the appearance of yellow wax. When the acid soap is subjected to gradual distillation there first comes over a nearly insipid phlegm, and then an oil more or less coloured and rancid, in proportion to the deepness of its colour, which congeals on cooling; there remains in the retort a little carbonaceous matter.

Nitric acid when cold and colourless acts but slowly on fixed oils, and the chief visible effect produced is that of rendering them thicker than before. But if ruddy nitrous acid is made use of, a much greater and more rapid alteration takes place, a violent effervescence comes on, attended by a copious discharge of nitrous gas. If a mixture of concentrated sulphuric and very high coloured nitrous acid be suddenly added, immediate combustion is for the most part the consequence, particularly if the oil is either naturally drying or made so by either of the methods already described. Nitric acid abstracted upon oil is decomposed, and oxalic acid is the result. If nitrous vapour or nitrous gas are thrown up into an inverted jar containing oil, they are rapidly absorbed, and the colour of the oil is changed to blue or green; after being put for a few hours in a cold place, the oil solidifies, and its colour becomes yellow or orange, a considerable disengagement of azot takes place, and in the course of a few weeks it becomes nearly white and very stiff.[e]

Muriatic acid produces little change in any of the fixed oils, but oxymuriatic acid thickens and bleaches them, and causes them to pass nearly into the state of wax.

None of the neutral salts are capable of combining with oil, nor of decomposing it at the common temperature, except the oxymuriat of potash: this mixed up in a metal mortar with a few drops of oil, and then struck smartly with the pestle, immediately detonates and takes fire.

Oil unites pretty easily with sugar or simple mucilage, and in this state is miscible with water into a white emulsive liquor.

The drying oils when mixed with lamp-black, or with almost any very dry vegetable fibre, and put into a box or close room, are very subject to undergo a rapid decomposition attended by great heat, which on the admission of fresh air, bursts into actual INFLAMMATION.

We shall terminate this article by some short notices concerning the qualities and method of preparation of the principal fixed oils.

Olive Oil.

The fruit of the olive tree (Olea Europea) when ripe, is of a dark purple colour, and both in size and shape resembles a long plum: it consists of a nut or stone covered by a fleshy pulp, in the latter of which are the cells that contain the oil: the interior nut also contains an oil, but of a bitter disagreeable taste. The fruit as soon as gathered is broken in a mill, care being taken to set the mill-stones at such a distance as to avoid crushing the nut of the olive. The pulp thus prepared is put into bags made of rushes, and subjected to a moderate pressure, by which a considerable quantity of a greenish semi-transparent oil is obtained, which from its superior excellence is called virgin oil. The marc remaining after this first operation is broken to pieces, moistened with a little warm water, and again returned to the press; a mixture of oil and water flows out, which soon separates spontaneously by rest. This oil though inferior to the former, is still of a very good quality and fit for the table. The marc being again broken to pieces, drenched with water, and fermented in large cisterns, is for the third and last time submitted to the full force of the press, by which a considerable quantity of oil is obtained, very valuable to the soap-boiler and other manufacturers. In some countries, particularly in Spain, the olives instead of being gathered by hand, are beaten down, by which the ripe and unripe are mixed together, to these also are added such as have fallen of themselves, and are therefore more or less decayed. Of this indiscriminate collection a large heap is made, which soon begins to ferment; in this state the olives are

[e] Priestley on Air. Method iii. p. 112, 136.

ground, and strongly pressed in the usual manner, by which mode of proceeding a larger quantity of oil is indeed obtained, and with less trouble, but of a rank disagreeable flavour, intolerable to any but those who have from childhood been accustomed to it.

Recently drawn virgin oil has a bland almost mucilaginous taste, with a slight but agreeable flavour: if exposed to the air in an open bottle or cask, a white fibrous and probably albuminous matter is deposited, the supernatant oil becoming clear, and of a dilute yellow colour; the oil being poured off into a fresh vessel, a second deposition takes place, after which the oil if put in clean glass vials, may be kept for a considerable time without alteration. If the oil is allowed to stand on the white matter, it becomes in a few weeks very rancid; and the common oil even when properly managed, cannot be preserved in casks longer than a year and a half, or two years at the farthest. The sp. gr. of olive oil is $= 0.9153$; it boils at about 500° Fahr. and congeals at 36° Fahr. The readiness with which it freezes renders it improper for lamps, especially in cold countries; but by previously exposing the oil in an open clear glass vial to the sunshine, it may be so far amended in this respect, as to continue fluid at 21° Fahr.[f] Olive oil is often sophisticated by poppy-seed oil, and thus is rendered somewhat drying, a property which the genuine produce of the olive never exhibits. In those countries where it is produced it is employed in food, as butter is with us: the inferior sorts are burnt in lamps, or made into soaps, for the most part of a finer quality than those that are composed of animal oils. It is used in medicine sometimes internally, but generally externally, combined with wax, litharge, &c. into cerates and plasters.

Cornel Oil.

The only oil resembling that from the olive, in being contained not in the seed but in the pulpy fruit of a vegetable, is cornel oil. The berries of this shrub (Cornus sanguinea, *Linn.*) being collected when quite ripe, and then laid in heaps for a few days in order to mellow, are to be reduced to a pulp, and pressed without heat in the usual manner. By this treatment, from 22 lbs. avoir. may be obtained somewhat more than four wine pints of a fat somewhat viscid oil, of a bright green colour, and equally destitute of any unpleasant flavour as the best olive oil. When heated with nitric acid it is converted to a lemon-yellow butter or wax. By boiling with litharge it becomes drying; when spread thin on water and exposed to the air for a month, it is converted into a white wax. It does not freeze so readily as olive oil, and lasts rather longer than this when used in a lamp.[g]

Almond Oil.

This is procured either from the sweet or bitter almond. The almonds are first put into a coarse hempen or hair sack, and shaken violently, in order to detach, by rubbing against each other and the sides of the sack, the outer brown skin, which if retained is apt to give a bitter taste to the oil: they are then bruised and made into a paste, and pressed in the usual manner. 100 lbs. of almonds afford by the first expression, 25 lbs. of oil, and from the marc when impregnated with the steam of hot water, may be procured 15 lbs. more of an inferior kind. Almond oil when fresh, is of a light greenish yellow colour, and is somewhat turbid, but by time it becomes clear and colourless: it is slightly sweetish to the taste, and has little or no odour. Its sp. gr. is $= 0.917$. The degree at which it congeals is variously stated at 19° Fahr. and 8° Fahr.; the former probably relates to the fresh-drawn oil. The only difference between the oil from sweet and that from bitter almonds is, that the latter may be kept the longest without growing rancid. On account of its high price, at least in most of the countries of Europe, it is almost entirely restricted to medical uses.

Poppy-seed Oil, or *Pink Oil*.

This oil is extracted by cold drawing from the seeds of the large white poppy (Papaver somniferum. *Linn.*) which is largely cultivated for this purpose in France, the Netherlands, and various parts of Germany. It is transparent and nearly colourless, and when well prepared has no other taste or flavour than a slight one of nut-kernels. Its sp. gr. is $= 0.9288$: it is one of the naturally drying oils, and like all of that class is frozen with difficulty; it may be cooled down to 0° of Fahr. without congealing. When employed in food it is scarcely to be distinguished from olive oil, and indeed this latter is very commonly adulterated with it. As to the quantity of oil yielded by a given weight of the seeds, authors are by no means agreed, and much no doubt depends not only on the mode of extracting it, but also on the season and country in which the seeds are produced: from 100 lbs. of fresh seeds, some state the produce of oil at 25 lbs. and others at 58 lbs.

[f] Sennebier, Ann. de Chem. xi. p. 93.

[g] Margueron, in Ann. de Chem xxxviii. p. 174.

It is used both for food and in the compofition of varnifhes, but is very unfit to burn in a lamp.

Linfeed Oil.

The feeds of the common flax, from which this oil is produced, confift of a white kernel covered by a thin brownifh fhell. As it is impoffible to feparate the fhell from the kernel, the entire feed muft be fubmitted to the prefs, but if thus treated without any previous preparation, the quantity of oil obtained is comparatively fmall on account of a ftrong mucilage that refides in the fhell, and abforbs a large proportion of the oil as it is forced out of the kernel. For this reafon, and becaufe the cold drawn oil is not fo fit for the purpofes to which linfeed oil is generally applied as that which is hot drawn, the following method is generally taken to deftroy the mucilage before the application of the prefs. An iron veffel like a fandbath, and capable of containing fome bufhels, is fixed in a furnace: it is then filled with linfeed and heated by a moderate fire, care being taken to ftir up its contents from time to time, that every part may be equally roafted; at firft there arifes an abundance of aqueous vapour, which as the heat is increafed is followed by denfe blackifh fumes of a very naufeous odour. The torrefaction being compleated, the pafte is preffed in the mill in the ufual way.

The proportion of oil yielded by this feed is about 20 per cent: its fp. gr. is =0.9403. It is not congealed except by a cold below 0° Fahr. its point of ebullition is about 600° of the fame thermometer. The cold drawn oil has a high yellow colour, is very unctuous and unpleafant both to the tafte and fmell; by expofure to the air and light it becomes drying. The hot drawn oil is of a high yellowifh red or deep wine colour, it is ftill more naufeous than the former; it is of a thicker confiftence, and dries without much difficulty in the air, more efpecially if it has been boiled with a little litharge. Linfeed oil is employed a little in medicine, but the great demand for it is in the coarfer kinds of painting, particularly fuch as is not much expofed to the weather, as floor cloths, &c.

Hempfeed Oil.

This oil is of a green colour and is ftrongly impregnated with the peculiar odour of the plant. The proportion of oil that hempfeed affords is from 20 to 25 per cent. In its general properties, ufes, and mode of preparation it clofely refembles the preceeding.

Oils of Muftard-feed, Cole-feed, Rape-feed, and Sunflower-Seed.

Thefe oils are lefs coloured and lefs highly flavoured than the two preceeding, they are very little liable to dry by expofure to the air, which, together with their moderate price, induces a large confumption of them by the wool-dreffers in order to preferve the wool from the attacks of moths and other infects; and by the leather dreffers.

Nut-Oil.

This is obtained chiefly by cold drawing from the kernels either of the walnut or of the hazle nut. In the warm climate of the South of Europe thefe fruits come to their full perfection, and will yield by proper management full half their weight of oil. Recent cold drawn nut oil is by many preferred to olive oil, on account of the exquifite nut flavour which it retains: the hot drawn has an empyreumatic tafte, and is no longer fit for the table; it is however in high requeft by the painter, as being eminently drying, much lefs coloured than linfeed oil, and capable of bearing the injuries of the weather better than any other oil.

Beech-nut Oil.

Several ineffectual attempts have been made to manufacture this oil with profit from Englifh Beech maft. Various caufes have probably concurred to occafion the failure, particularly the inexpertnefs in the method of extraction, and in all probability a real defect of oil compared to that contained in the beech nuts of France and the South of Germany. The following is the method adopted by fome manufacturers, and appears upon the whole to be the beft. The nuts when feparated from the outer prickly receptacle are paffed through a mill, the ftones of which are fet fufficiently wide to break off the outer fhell without materially bruifing the kernel, after which by means of the common winnowing machine the fhells are got rid of. The decorticated nuts are then thrown into fcalding water, and all thofe that fwim are rejected as being mouldy and worm eaten, and therefore communicating a bad tafte to the oil: the reft are reduced to a pulp, and then cold drawn, when they will be found to yield 15 per cent. of a clear light coloured nearly infipid oil, to the full as good as common olive oil. The marc being now flightly torrefied and again preffed, will afford 12 per cent. more of an inferior oil, and the dry refidue is an excellent food for cattle, much better than common oil cake.

Oil of Ben. Oleum Balani of the ancients.

This oil is procured by expreſſion from the decorticated ſeeds of the Guilandia Moringa, a tree that grows in Ceylon, Ethiopia, Egypt and Arabia. 100 lbs. of the ſeeds yield 23 lbs. of a yellowiſh limpid oil, inodorous, inſipid, and which does not become rancid by expoſure to the air. On this account it is much uſed by the Italians as the baſis of their perfumed oils, which are commonly prepared by filling a covered diſh with alternate layers of cotton ſoaked in Ben oil, and flowers of jaſmine, violet, orange, &c. after the diſh has been ſet in hot water, or in the ſunſhine for a few days, its contents are unpacked and the oil ſqueezed out of the cotton, which by this ſimple proceſs is found to be highly impregnated with the aromatic qualities of the flowers.

There are ſeveral other kinds of expreſſed oils employed in various countries as food, or in lamps, &c. but of which we ſhall only particularize the two following, as being ſpecimens of the vegetable butters.

Butter of Cacao.

This oil is procured from the chocolate nut, the fruit of the Theobroma Cacao. The nuts are firſt gently roaſted till the thin outer huſk ſhells off, and are then beaten up into a ſmooth thin paſte by the addition of eight times their weight of warm water. This mixture being then kept at a gentle boiling heat for ſome hours, a liquid oil riſes to the ſurface, which when the fire is withdrawn concretes into a ſebaceous matter of a grey colour, and amounting to about 45 per cent. of the entire nuts. This oil may be rendered nearly white by repeated waſhing in ſcalding water. It has little or no taſte, but retains for a long time the delicate flavour of chocolate, and appears to be the leaſt diſpoſed of any of the oils to become rancid. It is employed in America as an article of food, and in the compoſition of unguents and medicated ſoaps.

Palm Oil.

Many of the palms produce a hard nut like a date ſtone, but abounding in oil. Of theſe the two principal are the Cocos butyracea and Eleæis guineenſis. The fruit when ripe is heaped up and ſlightly fermented in order in ſome meaſure to ſoften it; being then coarſely pounded it is macerated in hot water, and thus by degrees parts with its oil, which collects on the ſurface of the water, and by cooling concretes into a ſolid cake: it is purified by waſhing in hot water and is then fit for uſe. It has a light lemon yellow colour, little or no taſte, but a high odour and flavour like that of the Florentine iris: by long keeping it becomes rancid, and then is nearly white and almoſt without odour. It is largely uſed by the negroes in Africa and the Weſt Indies as food, and in Europe is employed in medicine, and in the compoſition of the beſt yellow ſoap.

Oils Vegetable, Essential, or Volatile.

Theſe oils are ſo called becauſe they are evaporable at a moderate heat without decompoſition, and becauſe in them the odour or fragrance, or as it was called by the old chemiſts, the *eſſence* of vegetables reſides. They are not confined to any particular parts of a plant, but exiſt in minute cells diſtributed through the root, the wood, the bark, the leaves, the bloſſoms, and ſeeds. The part in which they occur leſs frequently than any other is the lobe or cotyledon of the ſeed, the peculiar ſeat of the fixed oil, while the huſk or cover of the ſeed is always more or leſs impregnated with volatile oil, the acrimony of which defends in ſome degree the rudiments of the young plant from the depredation of inſects.

The method of extracting the volatile oil differs for the moſt part very materially from thoſe which we have already deſcribed as practiſed for the fixed oils. Thoſe which are procured from the rinds of the lemon, the orange, and the bergamotte orange are the only ones capable of being obtained by expreſſion, which is performed in the following manner. A ſmall wheel with its circumference ſet with ſhort nails is put in motion, and a lemon or orange is applied to it till the whole of the yellow outer rind is thus raſped away: the raſpings fall to the bottom of the caſe in which the wheel turns, and when a ſufficient quantity is collected, are ſqueezed between two plates of glaſs; by this gentle preſſure the eſſential oil flows from the ruptured cells into any convenient veſſel placed to receive it, and undergoes no further preparation except that of being allowed to reſt till the water and other impurities have ſubſided.

A method analogous to that by which the vegetable butters are obtained is ſometimes practiſed in India for procuring that delicious and coſtly perfume the oil or *attar* of roſes. For this purpoſe a clean caſk or large glazed earthen jar is filled with roſe leaves carefully ſeparated from the calyxes, and ſpring water poured on juſt ſufficient to cover them: the veſſel with its contents is then ſet in the ſun for two or three days, and taken under cover during the night. At the end of the third or

fourth day small particles of yellow oil will be seen floating on the surface of the water, which in the course of a week will have increased to a thin scum: this is taken up by a little cotton tied to the end of a stick, and squeezed into a small vial.

The oil contained in the fragrant blossoms of those plants which have none in their other parts, as the violet, the mignonette, the jasmine, the tuberose, the hyacinth, and all the scented liliaceous plants, &c. although exceedingly odorous, is so minute in quantity and so easily destroyed by heat as to be incapable of being extracted in any other way than by means of the oil of ben, as described in the last article. The fragrant oil may afterwards be separated from the oil of ben in the following manner. Let a vial be half filled with a mixture of alcohol and perfumed oil in equal proportions, and shaken for a few minutes that every particle of each may come in contact with the other: then pour off the alcohol from the oil, which will be found to be nearly inodorous, having yielded its essential oil to the alcohol. Let this perfumed spirit be shaken again with successive portions of oil, till the richness of its fragrance is not sensibly increased, and then pour it into a bason containing two or three times its bulk of pure water: the water and alcohol will combine together, and the greater part of the essential oil will be liberated and will float at the top of the liquor, from which it may be scummed off by means of a little cotton. The liquor being afterwards submitted to very gentle distillation, the first portion of spirit that comes over will be found to be still very fragrant, and may be employed, mixed with fresh alcohol, in treating other portions of scented oil.

By far the greater number however of essential oils are obtained by direct distillation. If the substance to be treated is a fresh herbaceous plant it requires no previous treatment, but if it is a dried plant, a few hours maceration in water is advisable; if a bark or wood is to be distilled it must be rasped or cut into shavings and macerated for several days. This being done, a tinned copper still or alembic is to be charged with the solid materials closely rammed down, on which is to be poured just water enough to cover them, the head being then luted on and the refrigeratory filled with cold water, the fire must be lighted and so regulated as to keep the contents of the still constantly simmering, but scarcely boiling. The steam being condensed in the worm will form a small stream of water, and is to be collected in proper vessels till it comes off nearly insipid and inodorous, when the distillation is to be stopped. The first part of the produce being turbid from supersaturation with essential oil is to be kept for some hours in a cold place, during which time the excess of oil will separate from the water, and either float on its surface or sink to the bottom, according to its specific gravity. The compleat separation of the oil from the distilled water is effected by a very simple instrument called the Italian recipient, (described in the appendix) and the whole of the water drawn off in the first distillation is to be employed as far as it will go in the next, instead of plain water, by which it is manifest that the produce of oil in the second distillation will exceed that of the first, (other circumstances being equal) by all the quantity held in permanent solution by the water of the former process. Hence it is manifest that by this mode of proceeding, the amount of oil yielded by equal quantities of the same substance will form a constantly increasing series, till the whole of the water drawn off by each distillation is compleatly saturated with oil. This accounts in some degree for the great difference in the proportions of oil obtained by different chemists from the same plants; for as Bindheim has satisfactorily shown, it is not till the seventh, or even in some cases the tenth distillation that the produce of oil attains its *maximum*.

It is not only from the odorous vegetables themselves that essential oil may be procured, but also from such of the immediate products of vegetation as possess any odour; such are the balsams and many of the resins and gum resins. The process to be followed is distillation with water and precisely the same subsequent treatment as we have already described.

The peculiar odour of vegetables, when not in a state of decomposition, depending on the volatile oil that they contain, it will be obvious that the odours of the oils themselves must be equally various and therefore incapable of being described. The taste of all of them is exceedingly hot and pungent, but in some, particularly the oil of peppermint, is followed by a remarkable sensation of coldness: this however is merely a nervous sensation, the thermometrical temperature undergoing no change. The acrimony of some of the oils, as the oil of cloves, is so great as actually to destroy the outer skin of the tongue and of other sensible parts. The consistence of the essential oils is very various; some being as limpid as water, while others are thick and glutinous like the expressed oils. A

ſlight degree of cold is ſufficient for their congelation, at which time they aſſume the appearance of cryſtalline plates, which however muſt not be confounded with the priſmatic cryſtals that moſt of them depoſit by long expoſure to the air. The colours of eſſential oils are various; ſome are blue, others green, but the uſual colour is light yellow verging more or leſs by long keeping to reddiſh brown.

Eſſential oil is compleatly volatile without decompoſition at a heat leſs than that of boiling water; (hence if a few drops are ſpread on a piece of paper and then held for a minute or two before the fire, any ſophiſtication with expreſſed oil may be detected by the greaſe ſpot that will remain after the volatile oil has been entirely exhaled). It may however be detained in a higher heat by mechanical mixture with dry ~~clay~~ or ſand, and then it undergoes a partial decompoſition, carburetted hydrogen being given out and a little charcoal remaining in the receiver: the undecompoſed reſidue if ſubjected three or four times ſucceſſively to ſimilar treatment will be entirely deſtroyed.

Eſſential oils are highly combuſtible; they take fire on the application of an ignited body or by the electric ſpark, and burn with a large white flame ~~and~~ a denſe black ſmoak; a larger proportion of oxygen is required for their combuſtion than of the other oils, and a greater quantity of water is produced.

The eſſential oils, eſpecially the more volatile of them, deoxygenate atmoſpheric air very compleatly, as was firſt aſcertained by Prieſtley, which in part at leaſt accounts for the uneaſy ſenſations experienced by moſt perſons when in a cloſe newly painted room. In proportion to the oxygen abſorbed the oil becomes thick and coloured, more eſpecially if it is at the ſame time expoſed to the ſun, and at length nearly loſes its peculiar odour and approaches in conſiſtence to a ſoft reſin. In thoſe oils that are naturally thick a change of another kind takes place: a weakly acidulous water is produced and priſmatic cryſtals are depoſited, the reſidue of the oil becoming in the mean time concrete. Theſe cryſtals, which have been occaſionally miſtaken for camphor, are ſlightly ſoluble in hot water, and more ſo in alcohol, to which they communicate the property of reddening vegetable blues: when gently heated they melt and cryſtallize in needles by cooling; when treated by the blowpipe they evaporate, but do not inflame: from theſe characters they have been conſidered as an acid very analogous to the benzoic. It appears from the experiments of Margueron[h] that ſome oils when expoſed to a freezing mixture undergo the ſame change: at the moment of congelation a portion of highly odorant gas is diſengaged, a watery acid is produced and cryſtals are depoſited. Some eſſential oils however afford real camphor by evaporation, as Prouſt has ſhown, and as the reader will find fully detailed under the article CAMPHOR.

Oil that by long keeping in a half-cloſed bottle has become thick and nearly ſcentleſs, may be rectified by rediſtilling it with water and ſome of the freſh vegetable from which it was originally extracted, and this was often cited as a proof that the ſubſtances called eſſential oils were in reality compounds of reſin and the *ſpiritus rector*, or aromatic principle. But preciſely the ſame effect may be produced by means of alcohol or ſtill more readily by ether. This curious and important fact was firſt ſtated by De Roover[i], from whoſe experiments it appears that if thick ſpoiled oil be mixed with $\frac{1}{16}$ of ſulphuric ether for a few days and then diſtilled with pure water, more than half the oil will come over perfectly limpid and poſſeſſed of its peculiar odour, while the remainder will be left behind in the ſtill in the ſtate of a dark coloured reſin. The united weights of the diſtilled oil and reſin exceed that of the original oil, whence it is probable that the ether actually combines with part of the oil, and probably by ſupplying it with hydrogen, reſtores to it the liquidity and odour which it poſſeſſed at firſt. It is to be regretted that M. De R. did not follow up his experiments by treating the reſinous portion with freſh quantities of ether, ſo as to aſcertain whether it was poſſible to convert it in part or entirely into volatile oil as at firſt.

Eſſential oil is ſparingly ſoluble in water, from which it may be ſeparated by diſtillation, but is taken up much more abundantly by alcohol; this ſolution however is decompoſable by water, the greateſt part of the oil being ſeparated.

Both ſulphur and phoſphorus are ſoluble in eſſential oils equally well as in the fixed and with nearly the ſame phenomena: phoſphorized oil is luminous in the dark, has a fetid odour, and gives out phoſphuretted hydrogen by diſtillation: ſulphurized oil is of a yellow or brown colour, and gives out on diſtillation ſulphuretted hydrogen; it is often called *balſam of ſulphur*.

The ſtronger acids act more vigorouſly on the eſſential oils than they do even on the fixed.

[h] An. Chim. xxi. 174.

[i] Nich. Journ. 8vo. vii. p. 68.

Sulphuric acid causes a strong effervescence and evolution of heat, the oil is rendered thick and brown, and water is produced. Highly concentrated and fuming nitrous acid if poured suddenly on these oils occasions an instantaneous inflammation; but if somewhat diluted and added drop by drop a considerable effervescence takes place, accompanied by the disengagement of nitrous gas; the oil becomes thick and yellow and at length assumes the appearance of a soft resin: by washing in repeated portions of water all the acid is got rid of. The resinous matter thus procured is insoluble in water, but very soluble in alcohol, to which it gives a bright wine colour and a bitter sub-aromatic flavour; it is inflammable and exhibits most of the other properties of true resin.

The action of muriatic acid upon the volatile oils has been but little examined. When thrown in a gasseous form into oil of turpentine it blackens it and causes a precipitation of a species of CAMPHOR on subsequent washing with water. Oxymuriatic acid thickens the volatile oils and brings them nearly to the state of resins with little or no colour.

The alkalies combine though imperfectly and not without difficulty with the essential oils, forming a class of SOAPS, of which we shall speak more at large hereafter.

We shall close this article by the following list of the principal vegetables that afford essential oil, and of the proportions obtained from a given weight of the materials, premising that considerable allowances are to be made for difference of climate, of dryness in the plants, and other causes of uncertainty.

Name and state of the Vegetable.	*Quantity.*	*Amount of Oil.*	*Authority.*
Anise, seeds	16 lbs.	7 oz.	Beaumé
——— ditto	1 lb.	2 drachms	Neumann
Cajeput, seeds	1 lb.	15 grs.	Dehne
Camomile, flowers	82 lbs.	18 gros.	Beaumé
——— ditto	30 lbs.	1¼ oz.	Dehne
Capivi, balsam	1 lb.	6 oz.	Hoffmann
Carraway, seeds	6 lbs.	4½ oz.	Beaumé
——— ditto	1 cwt.	83 oz.	Lewis
Cedar, wood	1 lb.	2 drachms	Margraff
Cinnamon, bark	12½ lbs.	1 gros.	Beaumé
——— ditto	1 lb.	2½ scruples	Neumann
——— ditto	4 lbs.	6 drachms	Lemeri
——— ditto	3 lbs.	4 drachms	Cartheuser
Cloves	1 lb.	2¼ oz.	Cartheuser
Ditto	2 lbs.	5 oz.	Hoffmann
Coriander, seeds	164 lbs.	5 oz. 4 gros.	}
Cubeb, seeds	12½ lbs.	2 oz. 1 gros.	} Beaumé
Cummin, seeds	20 lbs.	12 oz.	}
——— ditto	1 bushel	21 oz.	Lewis
Dill, the fresh plant	60 lbs.	1½ oz.	} Beaumé
—— seeds	4 lbs.	2 oz.	}
—— ditto	4 lbs.	2 oz.	Lewis
Elecampane, fresh root	12 lbs.	½ gros.	Beaumé
——— ditto	12 lbs.	3½ drachms	Dehne
Fennel, seeds	75 lb.	30 oz.	Beaumé
——— ditto	1 lb.	8 scruples	Neumann
Feverfew, in flower	56 lbs.	1½ oz.	Beaumé
Ginger, root	1 lb.	1 drachm	Lewis
Hyssop, flowers	20 lbs.	6 gros.	Beaumé
——— leaves	2 cwt.	6 oz.	Lewis
Juniper, berries	10 lbs.	4 gros.	Beaumé
——— ditto	48 lbs.	6 oz.	Dehne
——— ditto	8 lbs.	3 oz.	Hoffmann, Cartheuser
Lavender, flowers	80 lbs.	1 lb. 9 oz.	Beaumé
——— ditto	48 lbs.	12 oz.	} Lewis
——— stalks and flowers	13½ cwt.	60 oz.	}

Name and state of the Vegetable.	*Quantity.*	*Amount of Oil.*	*Authority.*
Marjoram, whole plant & in flower	150 lbs.	15 oz. - -	Beaumé
Ditto - - - - - - -	85 lbs.	3½ oz. - -	Lewis
Myrtle, leaves - - - - - -	10 lbs.	1 gros. - -	Beaumé
Pepper Black, seeds - - - - -	1 lb.	2½ drachms -	Neumann
——— ditto - - - - -	2 lbs.	6 drachms -	Lewis
Peppermint, whole plant - -	4 lb.	3 drachms -	Lewis
——— in flower - - - -	1 cwt.	2½ to 6 oz. -	Original communication
Rhodium, wood - - - - -	80 lbs.	2 oz. - -	Beaumé
——— ditto - - - - -	1 lb.	3 drachms -	Neumann
Roses, entire flowers - - - -	80 lbs.	1½ drachm -	Polier
———petals - - - - - -	1 cwt.	4 drachms -	Tachenius
———ditto - - - - - - -	1 cwt.	1 oz. - -	Homberg
Rosemary, leaves - - - - -	24 lbs.	1 oz. - -	Beaumé
——— in flower - - - -	1 cwt.	8 oz. - -	Lewis
Rue, whole plant between flower and seed - -	21 lbs.	1 gros. - -	Beaumé
Ditto - - - - - - - - - -	72 lbs.	3 oz. - -	Lewis
Ditto seeds - - - - - - - -	10 lbs.	2 oz. - -	Beaumé
Saffron - - - - - - - - -	1 lb.	5 scruples -	Cartheuser
Sage, in flower - - - - - - -	48 lbs.	from 2½ to 3 oz.	Beaumé
——— ditto - - - - - - -	27 lbs.	6 drachms -	Lewis
Sanders Yellow, wood - -	1 lb.	2 drachms -	Cartheuser
Sassafras, wood - - - - - -	60 lbs.	from 12 oz. to 13½ oz.	Beaumé
———ditto - - - - - -	6 lbs.	2 oz. - -	Neumann
Savine, whole plant - - - -	23 lbs.	4½ oz. - -	Beaumé
———bark - - - - - - -	29 lbs.	9 oz. - -	Dehne
Spearmint, whole plant - -	96 lbs.	1 oz. - -	Beaumé
——— in flower - - - -	6 lb.	4½ drachms -	Lewis
Tansy, in flower - - - - -	72 lbs.	1½ oz. - -	Beaumé
Thyme, in flower - - - - -	2 cwt.	5½ oz. - -	Lewis
——— Lemon, in flower -	98 lbs.	2½ oz. - -	Lewis
——— dry - - - - - - - -	3½ lbs.	1½ drachm -	Lewis
Wormwood, the fresh plant -	712 lbs.	20 oz. - -	Beaumé
——— the dry leaves -	18 lbs.	1½ oz. - -	Lewis

The essential oils are employed in medicine, in perfumery, and in the composition of varnishes and of oil paints; to which latter purpose the oil of Turpentine is almost entirely appropriated.

Oils Vegetable Empyreumatic.

Almost every vegetable matter when subjected to dry distillation affords a quantity of oil, varying according to the nature of the substance, and the circumstances of the experiment. The oil thus produced has not been subjected to very accurate examination, yet may be described as possessing the following characters. Its colour is yellowish-red passing into blackish-red, it has a strong odour, and an acrid empyreumatic taste; it is more volatile than the fixed oils, but less so than the proper essential ones: by re-distillation with a little water it comes over nearly colourless, and more volatile than before, though still possessed of much of its empyreumatic flavour. Two of these oils namely, tar and birch oil, are of considerable importance; for an account of the first we shall refer the reader to the article Turpentine. The latter is prepared in Russia, by charring birch wood in a close oven, the watery acid and oil are collected in a large receiver, and the latter product being the lighest is skimmed off from the surface of the water. This oil has a peculiar scent, and is said to drive away worms and other insects, on which account it is used in the dressing of Russia leather, to which it communicates those properties that render it so much esteemed by the binders of books.

Oils Animal, Fixed.

All animals except those included in the

class of insects, contain oil; the quantity however of which, as well as the situation which it principally occupies in the body, is subject to considerable variety. In all cases it is contained in peculiar receptacles of cellular membrane; but these receptacles in quadrupeds are for the most part but sparingly dispersed among the muscular fibre, are more abundant in the bones, and most so of all in the cavity of the abdomen, and especially attached to the kidneys. The hog however is an exception to this, the principal part of his fat being deposited between the skin and the muscles. In birds the chief seat of the oil is immediately below the skin, and in water-fowl it is particularly secreted by a collection of glands in the rump. In the warm blooded fish, as the whale, the oil is chiefly contained in the head and jaw-bones, and is interposed in vast abundance between the skin and the muscular flesh. In the cold blooded fish it is contained in the liver, as in the shark, the cod, and the ling; or is dispersed through the whole body, as in the sprat, the herring, and pilchard.

While the fat remains in the living body it is always in a fluid or semi-fluid state, but after it has been extracted and is exposed to the common temperature, a remarkable difference in its consistence is observed. The oil or fat investing the kidneys of quadrupeds is called suet or tallow, and is the most solid and hardest of any; the next in hardness is the fat of the bones, and that in which the muscles are imbedded is the next in degree; the fat of the hog (called lard) is the least solid. The fat of birds is seldom so solid as hog's lard, and in many species is actually fluid. The fat or oil of fish is almost always fluid at the common temperature. Besides the above varieties of animal oil, there is yet another contained in the yolk of eggs, and which may be extracted by simple pressure after the yolk has been coagulated by heat.

Animal oil in its purest state is obtained by cutting fresh suet into shreds and liquefying it in boiling water, and then passing it through a piece of thin gauze, in order to separate the cellular membrane. When thus purified it is of a yellowish-white colour, moderately hard, of a mild taste, and nearly destitute of odour or flavour: it is combustible, like the fixed vegetable oils, and agrees also with these in the changes produced upon it by the alkalies and other chemical re-agents. All the animal oils however belong to the class of unctuous or fat oils, none of them being either drying in itself or capable of becoming so by means of litharge or other substances.

When fat is exposed to dry distillation, as soon as it acquires the temperature of about 400° it emits a white acrid and disagreeable vapour; as the heat increases some of the oil comes over into the receiver, and what remains in the retort acquires a blackish tinge; empyreumatic, acetous, and SEBACIC acids, then make their appearance, together with carburetted hydrogen and carbonic acid of a most remarkably offensive odour. This circumstance shews that there is a real difference between animal and vegetable oils, though it has not yet been pointed out by chemical analysis. The coarser kinds of animal oil being extracted by means of putrefaction and a strong heat, possess a much more disagreeable odour than any of the vegetable oils, and when rancid disengage ammonia by the action of the fixed caustic alkalies, in which also they differ from the latter.

The fish oils when rancid, and from the mode of their extraction they never are otherwise, are for the most part thick and glutinous, which in some measure disqualifies them for burning and for some other uses to which they are applied. Many attempts, for the most part without success, have been made to bring them to a better state, but as appears from the experiments of Mr. Dossie,[k] they may be considerably improved by means of fixed alkali and chalk, by which the albumen and gluten are thrown down, and the supernatant oil after due rest may be poured off in a fluid state, and very sensibly amended both in consistence, in odour, and in fitness for burning.

Animal oils are substances of great economical importance. They are used as food, and in medicine as the base of various unguents: they largely employed in the manufacture of soap, and for burning either in lamps or in the form of candles.

ANIMAL OIL VOLATILE, or Dippel's Oil.

As in the vegetable kingdom oil is produced by the destructive distillation of various substances that contain none in their natural state; so it is with respect to the animal kingdom. If albumen, or gluten be distilled at a dry heat, there arises together with the ammonia, and carburetted hydrogen, a quantity of fetid black oil; this was made the subject of various experiments, first by Dippel, a chemist of Berlin, and afterwards by Rouelle. From the concurrent labours of these enquirers it appears that

[k] Phil. Mag. xv. p. 105.

of this oil is rectified by three successive distillations from the surface of water, or by a greater number without water, it becomes at length quite colourless and transparent; it has a powerful but somewhat aromatic odour, and is nearly as light and volatile as ether. It contains a little ammonia, and hence changes the colour of syrup of violets green, it is sparingly soluble in water, and largely so in oils, ether, and alcohol. It combines both with acids and alkalies into imperfect soaps; it is very inflammable, and like the vegetable essential oils, may be set on fire by strong nitrous acid. If exposed even to the light it is partly decomposed, losing its transparency, and becoming of a brown colour. It was formerly employed in medicine, but is now wholly disused.

Oil Mineral, or *Petroleum*. See Bitumen.

Oil of Wine. See Ether.

Oil of Vitriol. See Sulphuric Acid.

Oil of Tartar, *per deliquium*. See Carbonat of Potash.

Oisanite. See Anatase.

Olefiant Gas. See Carburetted Hydrogen.

Olive Oil. See Oils Vegetable Fixed.

OLIVIN. *Volcanic Chrysolite. Peridot granuliforme.* Hauy.

Its colour is between asparagus and olive-green, but by exposure to the weather it becomes yellowish-brown. It occurs imbedded or disseminated in basalt, and sometimes in rounded pieces, also, though rarely, in small rectangular prisms. Internally its lustre varies between glimmering and shining, and is vitreous passing into resinous. Its fracture is more or less imperfectly conchoidal, passing into splintery and uneven. Its fragments are indeterminately sharp-edged. When in large pieces it exhibits granular distinct concretions. It varies from semi-transparent to translucent. It is hard, but less so than quartz; it is brittle and easily frangible. Sp. gr. 3.22 to 3.26. It is nearly infusible before the blow-pipe without addition; and loses its colour by digestion in nitric acid. It has been analysed by Klaproth with the following result:

48.	to	52	Silex
37.	—	38.5	Magnesia
0.25	—	0.20	Lime
12.5	—	12.	Oxyd of iron
97.75			
Loss 2.25			
100.			

It occurs only in proper basalt, and not in any other rock of trap formation. It is very easy of decomposition, to which circumstance many basalts owe their porous texture. It is found very abundantly in Bohemia and other parts of Germany, also in France, Britain, Norway, and Sweden.

OOLITE. See Limestone.

ONYX. See Chalcedony.

OPAL.

Of this mineral there are the four following subspecies.

1. Subs. Noble Opal. *Edler Opal*, Wern. *L'Opale noble*. Broch.

Its colour is milk-white, or pearl-grey, and when held between the eye and the light is pale rose-red and wine-yellow: by reflected light it exhibits, as its position is slightly varied, the clearest and most beautiful iridescent colours, particularly verdegris and emerald-green, gold-yellow, fire-red, bright-blue, and pearl-grey; all these tints are often exhibited in the same specimen, but when only one colour is present the green is the most esteemed. It occurs in mass, disseminated and in small veins. Its internal lustre is vitreous and brightly shining. Its fracture is conchoidal. Its fragments are indeterminate sharp-edged. It is moderately translucent passing to semi-transparent, and even transparent. It is moderately hard and very brittle. Sp. gr. 2.114.

Before the blow-pipe it crackles and flies, and becomes of an opake white, but does not melt. It is composed, according to Klaproth, of

90	Silex
10	Water
100	

It occurs disseminated in clay porphyry. It was formerly found near Freyberg in Saxony, but is at present met with only at Cscherwenitza, near Kaschau, in Upper Hungary.

It is the most beautiful of the gems, and among the Eastern nations is in particularly high estimation. In Europe its value though considerable, is inferior to that of the other gems from its softness and liability to split on a sudden change of temperature. It is chiefly employed in necklaces, and ear-rings, and finger-rings.

The most beautiful varieties are called oriental opal, but there is no satisfactory evidence to shew that this substance has ever really been found in the East.

Some varieties of opal, from exposure to the

weather, are dull and opake, probably in consequence of having lost part of their water; but by immersion in this fluid, their minute pores become again filled, and they then exhibit the usual play of colours. Such stones are called hydrophanes, and are in high estimation.

The most beautiful opals known are in the Imperial cabinet of Vienna: one is a piece about five inches long, and two and a half in diameter: another is of the shape and size of a hen's egg. Both are remarkably rich and splendid.

2. Subsp. COMMON OPAL. *Gemeiner Opal*, Wern. *L'Opale commune*, Broch.

Its colour is greyish, greenish, yellowish or milk-white, hence it passes into apple green, honey and wax-yellow, and sometimes, though rarely, into tile red, or flesh red. The milk white variety appears by transmitted light of a wine yellow. It occurs massive, disseminated, and in angular pieces. Its lustre internally is between vitreous and resinous, and is bright shining. Its fracture is conchoidal. Its fragments are indeterminately angular and sharp-edged. It varies from translucent to transparent. It is moderately hard, brittle, and easily frangible. Sp. gr. 1.95 to 2.01.

It is infusible before the blow-pipe without addition. Two varieties, one from Kosemutz and the other from Telkobanya, have been analysed by Klaproth with the following results.

	Kosem.		Telkoban.
Silex - -	98.75	—	93.5
Alumine -	0.1	—	0
Oxyd of iron	0.1	—	1.
Water - -	0.	—	5.
	98.95		99.5

It occurs chiefly in porphyry; but also in granite, gneiss, amygdaloid, and serpentine.

The green variety is found at Kosemutz in Silesia, where it accompanys chrysoprase in a bed of serpentine. In Iceland it alternates with chalcedony. It is also met with in various parts of Saxony and Bohemia, near Florence in Italy, Telkobanya in Hungary, in the North of Ireland, in Cornwall, in Brittany, and in the Faroe islands.

Several of the varieties of common opal as well as of the noble opal, are hydrophanous.

3. Subsp. SEMI-OPAL. *Halbopal*. Wern. *La Demi-Opale*. Broch.

Its usual colours are yellowish, greenish, and milk-white, also ash-grey, and greyish-black, apple-green, olive-green, honey-yellow, yellowish-brown, and chesnut-brown. Its colours are more dull and muddy than those of common opal, and they often occur in spots, bands, and clouds. It occurs massive, disseminated, tuberous, reniform, botryoidal and stalactitic. Internally it is glistening or shining. Its fracture is imperfectly flat conchoidal, verging on even. Its fragments are indeterminately angular sharp-edged. It is more or less translucent, is moderately hard, brittle, and easily frangible. Sp. gr. 2.54.

It is infusible before the blow-pipe without addition. Two varieties, the one from Telkobanya, and the other from Menil Montant, have been analysed by Klaproth, with the following results.

	Telkob.		Menil.
Silex - -	43.50	—	85.5
Alumine -	0.	—	1.
Oxyd of iron	47.	—	0.5
Lime -	0	—	0.5
Water -	7.5	—	11.0
	98.0		98.5

It occurs in veins in porphyry and amygdaloid, and in metalliferous veins in granite and gneiss. It usually accompanies common opal, and is found in the same places with it. Fossil teeth also are occasionally found penetrated by this mineral.

4. Subsp. WOOD OPAL. *Holzopal*. Wern. *Opal Ligniforme*. Broch.

Its colours are greyish and yellowish-white, also ochre-yellow, yellowish-brown, ash-grey, and greyish-black. It occurs in large pieces, which have the form and texture of wood. Internally it has a glistening somewhat resinous lustre. Its cross fracture is conchoidal, but its longitudinal fracture is broad splintery. Its fragments are indeterminately angular sharp-edged. It is translucent, moderately hard, and easily frangible. Sp. gr. 2.6.

It appears to be wood penetrated with opal, and is found near Schemnitz, and at Telkobanya in Hungary.

ORPIMENT. See ARSENIC.

ORPIMENT NATIVE. See ARSENIC, Ores of.

ORES.

An ore is a metal in the state in which it exists in the earth. It may be either native, that is, pure and uncombined with any other substance, or alloyed with another metal, or in the state of an oxyd, or a sulphuret, or a carburet, or of a metallic salt. It is also mixed in almost every case with various earthy minerals. For a par-

ticular description of the ores of each metal, of their analysis, and the methods pursued in their reduction, see the first, second, and third sections, in the account of each metal.

OSMIUM. See PLATINA.

OXALIC ACID. *Sauerkleesaure.* Germ. This acid is found frequently but not abundantly native, in various combinations, and it is also produced by the mutual action of the nitric acid upon a vast number of vegetable and animal substances. It is found native in a few acid vegetable juices, and in tolerable abundance in the expressed juice of the *sorrel* plant (Oxalis Acetosella. *Linn.*) naturally united with a quantity of potash not sufficient for compleat saturation, forming an acidulum which has long been prepared for culinary and medicinal purposes in some parts of Europe, and sold as the *Essential Salt of Sorrel*, long before its real nature was discovered. This acid is found in some species of urinary calculi.

The oxalic acid is artificially prepared by boiling a sufficient quantity of nitric acid with a variety of vegetable and animal substances, such as sugar, mucilage, alcohol, silk, animal jelly, &c. &c. and many of the other vegetable acids (the acetous excepted) are convertible into the oxalic by the action of the nitric acid.

The oxalic acid as artificially prepared, was first discovered by Bergman, who has given a very valuable essay on the subject. This eminent chemist prepared it by distilling nitric acid from sugar, and hence he termed it the *Acid of Sugar*. But as the acid of the native salt of sorrel was soon after discovered by Scheele to identical with the acid of sugar, the term *Oxalic Acid* has been more commonly adopted, and the combinations of this acid with the various bases, have been termed *Oxalats*.

This acid is prepared from sugar, very simply and easily by the following process: put a small quantity of white sugar into a tall glass matrass, with a narrow neck, add thereto six times its weight of concentrated nitrous or nitric acid, of moderate strength, apply heat, and bring it gradually to boil, during which the sugar speedily dissolves in the acid, and then decomposes it with evolution of abundance of nitrous vapour. Continue the boiling for about ten minutes, then set the liquor by to cool, when it will deposit regular crystals of oxalic acid. Evaporate the remaining liquor considerably, and by cooling another crop of crystals may be procured, and sometimes a third. Redissolve all the crystals in as much water as will take them up when boiling, and by cooling slowly the crystals will again separate in a more regular form, and freed from the adhering nitric acid. Dry these crystals on blotting paper, and they are the pure oxalic acid. A retort and receiver may be used for the process instead of a matrass, when it is an object to save the superfluous nitrous acid. About 58 parts of oxalic acid may thus be obtained from 100 of sugar.

The oxalic acid when in a regular form, crystallizes in four-sided prisms, the faces of which are alternately broad and narrow, and terminating in dihedral summits. These crystals do not deliquesce, but by exposure to the air they fall into a white powder.

This acid has a very pungent, and when diluted, a very grateful sourness. The crystals dissolve in their own weight of boiling water, and twice their weight of cold water.[a] The specific gravity of a cold saturated solution is about 1.06. This acid has all the common properties of acids, of changing vegetable colours, and forming neutral salts with the alkaline, earthy, and many metallic bases. It also forms acidula with all the alkalies, when the proportion of acid predominates.

This acid, like all the other vegetable acids, is decomposed, and its acid properties destroyed by heat, more or less compleatly in proportion to the degree of heat. If heated in a retort with a gentle fire the water of the crystals first comes over, amounting to about $\frac{3}{10}$ of the whole, and the acid fuses. On encreasing the fire, the acid grows brown, and part of it is sublimed as a white saline crust, but the greater part is resolved into carbonic acid, and carburetted hydrogen, which come over in large quantity, having a pungent empyreumatic smell. The residue in the retort entirely burns away in the open air, without leaving any ash.

Alcohol when boiling readily dissolves somewhat more than half its weight of oxalic acid. On cooling, a small portion is deposited in small scaly crystals, but the greater part remains in solution. The alcoholic solution when heated yields a portion of alcohol holding some of the acid dissolved, and also a very small quantity of an imperfect ether.

Sulphuric ether dissolves oxalic acid, though with difficulty.

Sulphuric acid heated upon the oxalic blackens it, and the two substances are mutually decomposed in part.

The nitrous or nitric acid readily dissolves

[a] Bergman, on the Acid of Sugar.

the oxalic, and if the former is in sufficient quantity, and the mixture long boiled, much nitrous vapour is given out, no oxalic acid is found in the liquor, but the whole is converted into carbonic acid and water.

The muriatic and acetous acids simply dissolve the oxalic, but do not decompose it.

The composition of this acid according to Fourcroy and Vauquelin, is 77 *per cent.* of oxygen, 13 of carbon, and 10 of hydrogen, so that it appears to be one the most oxygenated of all the known acids.

Before we proceed to describe the salts which it forms with the different bases, some observations may be added on the circumstances of its formation.

The oxalic acid is found but rarely native, but is readily produced by the action of nitrous acid on almost every soluble vegetable matter, and most animal matters. During this action the nitric acid is obviously decomposed, and much nitrous gas given out, and hence the product must contain much of the oxygen which the nitric acid parts with. But it appears that the formaation of oxalic acid is not in any case a simple oxygenation of carbon and hydrogen, but a much more complicated operation, in which according to well-established laws of affinity, specific proportions of carbon and hydrogen unite with a certain portion of oxygen to form oxalic acid, whilst at the same time other portions of the same bases form different products. Hence it is inaccurate to state as is sometimes done, that *sugar* is the base of the oxalic or saccharine acid, since it is a compound of hydrogen and carbon derived from the sugar, and which the action of the nitrous acid causes to be separated in the proportions necessary for that purpose. Hence the utmost action of the nitric acid on oxalic acid differs from that which it exerts on sugar, for in the former case only carbonic acid and water are formed, whereas in the latter there is generated a quantity of acetous acid.

The *Malic Acid* appears to be produced along with the oxalic, in almost every instance yet examined, and it forms the greater part of the mother liquor, or fluid part from which the oxalic separates by crystallization. The malic acid is also chiefly (but probably not entirely) convertible into oxalic by the further action of nitrous acid, and hence it is in some sense an intermediate state between oxalic acid and the hydro-carbonous base previous to oxygenation. This is shewn by many experiments of Scheele. This excellent chemist distilled equal parts of nitric acid and sugar,[b] stopping the process when the mixture in the retort had acquired a brownish colour, which indicated that all the acid was decomposed. The liquor was acid and of a syrupy consistence: on adding lime-water, some oxalic acid separated in the form of oxalat of lime. The remaining liquor was then saturated with lime (which occasioned no further precipitation) after which it was coagulated by alcohol, the coagulum decomposed by acetite of lead and sulphuric acid (in the way described under the article *Malic Acid*) and a quantity of pure malic acid was produced. On the other hand when the proportion of nitric acid is much greater, the product of oxalic acid increases, and that of malic diminishes.

The same excellent chemist found gum-arabic treated with nitric acid, to yield a mixture of malic and oxalic acid (see the article *Mucilage*). Manna, the same; sugar of milk the same, together with the saccholactic acid (see *Milk*). Salep the same, together with oxalat of lime; aloe, colocynth, and some of the resinous gums the same, but in smaller quantity; many of the vegetable extracts the same, together with some oxalic acidulum, or super-oxalat of potash (the potash being doubtless furnished from the acetite of potash which Vauquelin has found to exist in extracts). Of the essential oils only that of parsley could be made to furnish these acids, which it did in abundance, and was totally resolved into them.

Several animal matters were then treated with nitric acid in the same way. On one part of glue were poured two of nitric acid, much nitrous vapour was given out on heating, the glue was dissolved, and the next day crystals of oxalic acid appeared in the liqour. The uncrystallized residue saturated with chalk, and treated with acetite of lead and sulphuric acid, gave the malic acid. Isinglass, the white and yolk of egg, and blood, gave the same products. During these processes with animal matters, as this excellent chemist observes, a quantity of thick grease separates, little nitrous gas or carbonic acid is given out, but an abundance of *vitiated air* (azot). Another remark equally important is that whenever the oxalic acid is produced by the action of the nitric on animal or vegetable substances, a quantity of acetous acid is found in the receiver, mixed with the distilled nitrous acid. This latter discovery appears to have been made nearly at the same time by Scheele and Westrumb.

[b] Journ. de Phys. tom. 28. p. 412.

Alcohol treated by nitrous acid affords a large quantity of oxalic acid, as already noticed under the article ETHER *Nitrous*, hence it is always procured from the residue of the distillation of this ether. But the proportions of nitrous acid and alcohol which give the most oxalic acid, are different from those that produce the most ether. The latter are about 2 of acid to 3 of alcohol, but the former should be about 3 of acid to 1 of alcohol. M. Sage[c] mixed together in a retort 18 oz. of strong nitrous acid with 6 of alcohol, in half an hour the mixture boiled spontaneously, and some ether mixed with nitrous vapour distilled off. The residue evaporated to about one ounce gave ¼ of an ounce of oxalic acid.

The production of oxalic acid from animal substances, discovered by Scheele, has been examined with great accuracy by Berthollet in his excellent memoirs on the nature of animal matter.[e] He selected silk for his first experiment on account of its apparent uniformity of composition. On distilling silk with seven or eight times its weight of nitrous acid, the whole was resolved into a blueish liquor, which yielded a large quantity of oxalic acid, besides which when the liquor was cold there was collected a thick scum of an oily or greasy matter, similar no doubt to that which had been observed by Scheele in his experiments.

M. Berthollet on subjecting a number of animal matters to the same process, obtained from all oxalic acid, and this animal grease, but in very varying proportions. He takes no notice of the malic acid, which however must have been formed at the same time and remained in the solution. Of all these substances wool gave the greatest quantity of oxalic acid, yielding nearly half its weight, which is more than is procured from sugar or any known vegetable matter. Skin and hair gave nearly as much as wool. Muscular flesh, well washed, gave hardly any oxalic acid, but an unusually large proportion of animal grease. This latter when in large proportion, closely adheres to the oxalic acid, renders it yellow, and difficult to crystallize. This kind of grease is very different from the animal or vegetable oils, and gives much ammonia by distillation. It appears to be derived chiefly from the azotic part of the animal substance, since it abounds most in those parts that yield most azot, and is not produced in a similar treatment of vegetable matter: whereas the basis of the oxalic acid is unquestionably a mixture of carbon and hydrogen.

In no instance is oxalic acid produced without the sensible disengagement of nitrous vapour, and the consequent decomposition of the nitrous acid employed. Therefore it generally requires the assistance of heat for its production. Thus M. Berthollet found that silk and nitric acid digested at the heat of 70° gave out a large quantity of azotic gas, the silk was dissolved, and some of the animal grease separated, but no oxalic acid was formed at that period, (since no precipitation was produced by lime-water), but on raising the temperature nitrous gas was evolved, and oxalic acid was generated.

No other agent but the nitrous acid has been yet found capable of producing the oxalic acid. Even the oxymuriatic acid, one of the most powerful of all the oxygenating agents, fails to convert sugar into oxalic acid, but in its stead generates some acetous acid, and probably carbonic acid and water.

It is very commonly represented that there is a regular gradation of oxygenation in certain of the vegetable acids, that is to say, that the *same hydro-carbonous base* with a small quantity of oxygen produces the tartareous acid, with a greater quantity the citric, and so on, and thus by merely encreasing the doses of oxygen it passes from the tartareous through the several states of citric, malic, oxalic, and acetous acids, and lastly is totally convertible into carbonic acid and water. This last position is certainly true, for as all these acids appear to contain only carbon, hydrogen, and oxygen in different proportions, the ultimate effect of oxygenation is to convert them into carbonic acid and water, but no unexceptionable experiment has yet been given in which any given quantity of one of these acids has been *totally* converted into another acid by the action of nitric acid.

In all these changes therefore there appears to be a new arrangement of the proportions of the hydro-carbonous basis as well as of the oxygen, and at least two, (and often more) substances are generated, however simple the process appears to be. It is scarcely possible to assign a satisfactory reason for many of the changes that take place, and to explain why in some circumstances the mucous acid and vinegar should be formed, in others, the oxalic and malic acids, in others vinegar and carbonic acid, but from the much more frequent production of the oxalic than of any other acid, we may infer that he proportions in which its constituents exist, are those in which the mutual

[d] Mem. de l'Acad. for 1785. p. 233.

[e] Ditto for 1780 and 1785.

affinity is extremely strong and scarcely to be broken but by the combined effect of the most powerful agents. It appears probable too from Scheele's researches, that the malic acid is in most instances a necessary consequence of the production of the oxalic, but not being crystallizable, nor very readily detected, it has probably been most commonly overlooked.

The oxalic acid is a valuable test in chemical experiments to determine the presence of lime in liquids, in whatever combination this earth exists. The precautions required in its use will be mentioned under the article *Oxalat of lime*.

The affinities of oxalic acid are in the following order: lime, barytes, strontian, magnesia, potash, soda, ammonia, alumine, and metallic oxyds.

OXALATS.

The oxalic acid unites with all the alkalies, earths, and most metallic oxyds, forming salts of which a very few only are of importance. This acid like the tartareous, combines with the alkalies in two different proportions, in each of which it forms crystallizable salts. One of these states is with the acid in excess, forming therefore salts known by the general term of *acidula*, the other is when the two ingredients are in perfect saturation. Of these the *Acidulous oxalat of potash*, or according to Dr. Thompson's useful nomenclature, the *Super-oxalat of potash*, has been examined with the greatest care.

All the oxalats are readily decomposed by heat, the acid burning off, and leaving the base carbonated.

Oxalic Acidulum. *Super-oxalat of Potash. Salt of Sorrel.*

A salt has long been prepared in several parts of Europe from the juice of the sorrel plant, for medicinal and other purposes, particularly in Swabia, Thuringia, and some parts of Switzerland. The method of making it has been described by Savary, Cartheuser, Weigleb, and others, and is very simple. Large quantities of the plant are collected and exposed to considerable pressure in a mill, (or in any other way) and the turbid juice thus expressed is allowed to stand for some days till much of the feculence has subsided. The clear liquor is then evaporated to one half, and set by in a cool place, and after some days a quantity of small-grained crystals are deposited. These are removed, and the liquor further evaporated, by which a second crop of crystals is collected, and sometimes a third or a fourth is got by the same means. The crystals are at first very mucilaginous and impure, but by re-solution and evaporation they become clean, and then appear in the form of small white needles, in which state they are sold at a high price for taking out iron-mould spots from linen, and for medicinal uses. According to Savary, 50 lbs. of the fresh plant yield about 25 lb. of juice, from which 2¼ oz. of the essential salt may be extracted. Cartheuser[a] obtained much more, one pound of the plant giving as much as 1½ dram, which would be in the proportion of nearly 9½ oz. from 50 lbs. of the plant, but probably this was less pure.

The taste of this salt is very sour, setting the teeth on edge, but has nothing bitter or unpleasant. The salt is hard and brittle, and decrepitates in the fire. It is very commonly adulterated by sulphat of potash,

It was Scheele that first discovered the true composition of this salt, and shewed it to be composed of potash with excess of an acid, which by every test was identical with the acid of sugar which had been lately discovered by Bergman. The method pursued by Scheele was the following: some warm water was saturated with salt of sorrel, and a solution of acetite of lead was then added as long as any precipitate appeared, which last was edulcorated with warm water. This consisted of the oxalic acid united to the oxyd of lead, whilst the supernatant liquor contained acetite of potash produced by this double decomposition. This precipitate was then decomposed by digestion with sulphuric acid, by which the oxalat of lead was converted into an insoluble sulphat, and the clear liquor contained the pure oxalic acid, which was obtained in its crystalline form by due evaporation and cooling. The proportion of sulphuric acid required was determined by decomposing by this acid separately as much of acetite of lead as had been used, and noting the quantity of acid employed. The acid thus obtained from the salt of sorrel was then examined chemically, and found to agree exactly in all its properties with that obtained from sugar by the nitric acid. A salt precisely resembling the salt of sorrel was then reproduced by adding gradually to a solution of the acid some liquid carbonat of potash, much less than sufficient for saturation, and during the effervescence occasioned by the mixture, a number of small saline spiculæ fell down, which when examined were found to be exactly the same with the native salt of sorrel.

The oxalic acidulum may also be produced by adding pure oxalic acid to nitre, as the same

[a] Murray, Appar. Med. vol. 3.

eminent chemist also discovered, the affinity of this acid to that portion of potash necessary to form the acidulum being greater than that of the nitric acid for potash. In the same manner the oxalic acid will partially decompose many other of the salts with potash, such as the muriat, acetite, &c. In these cases the super-oxalat of potash being much less soluble than the other salt, precipitates in small needled crystals.

This salt however readily dissolves in hot water, requiring no more than about its own weight, but the greater part separates by cooling. The solution is not decomposed spontaneously by long keeping,[b] in which respect it differs from the tartareous acidulum. The sulphuric, nitric, and muriatic acids decompose this salt only at a boiling heat.

Oxalat of Potash.

When the oxalic acid is super-saturated with potash and slowly evaporated, elegant prismatic crystals are formed, in which neither the acid nor alkali predominate. This salt may be made by adding to the acidulous oxalat somewhat more potash than is necessary for saturation. This salt is much more soluble in water than the last mentioned. Alcohol dissolves it with difficulty. It is partially decomposed by the sulphuric, nitric, and muriatic acids without heat, that is to say, a portion of the potash is abstracted, and the remainder passes to the state of the super-oxalat. But with the assistance of heat it is entirely decomposed.

Oxalat of Soda.

The oxalic acid united to a smaller quantity of soda than will saturate it, forms a species of acidulum which has been but little examined. Saturated with soda, a salt is produced difficult of solution, and which separates in small crystalline grains.

Oxalat of Ammonia.

Ammonia also unites with oxalic acid in two proportions. When as an acidulum, it forms salt in small crystals, and of difficult solubility, but when perfectly saturated the salt crystallizes in large four-sided prisms. These lose about $\frac{1}{2}$ of their weight by a gentle heat, and are very soluble in water but not in alcohol. This combination of oxalic acid is the most useful for detecting the presence of lime, as will be presently mentioned.

Besides these simple salts with the oxalic acid and alkalies, several triple salts (most of them crystallizable) may be formed by saturating the super-oxalat of one alkali by a different one; thus if the super-oxalat of potash is saturated with soda, a triple neutral salt is obtained, consisting of oxalic acid, potash and soda. In like manner ammonia readily combines with the super-oxalat of potash and soda. In this as in other respects, the habitudes of this acid strongly resemble those of the tartareous acid.

Oxalat of Barytes.

This acid forms with barytes a salt which when the acid is in excess, appears in the form of pellucid angular crystals. Boiling water dissolves a small portion, but converts the remainder into a white powder, rendered insoluble by losing its excess of acid, which the water abstracts. On cooling, most of that portion which had been dissolved separates in small crystals. This salt is decomposed by sulphuric acid.

Oxalat of Strontian.

By pouring oxalat of potash into muriat of strontian, an insoluble white powder is obtained, composed according to Vauquelin[a] of $59\frac{1}{2}$ strontian, and $40\frac{1}{2}$ acid.

Oxalat of Lime.

The oxalic acid attracts lime with greater force than any other acid, and therefore is capable of decomposing compleatly all the known calcareous salts. Hence the great utility of this acid in detecting lime in every soluble combination. Oxalat of lime is insoluble in water, so that when this acid is added to a solution containing lime, a white precipitate of oxalat of lime falls down, from which, when collected, washed, and dried in a moderate heat, the actual quantity of lime may be readily inferred. By very accurate experiments Dr. Marcet[a] found that 100 parts of oxalat of lime dried at 160° were produced from 117 of selenite, and the quantity of lime in the latter, also dried at 160°, may be reckoned to be about 41. The oxalat of lime however, though insoluble in water, dissolves in many of the acids without being decomposed, and therefore when any considerable excess of acid is present, less oxalat of lime will be obtained than is really formed, and which will lead to error. On this account it is necessary to saturate any excess of acid before the oxalic test is used, and as an additional precaution, the oxalic acid should be saturated with an alkali, which will not in the least diminish its power of precipitating lime. The oxalat of ammonia is generally preferred.

[a] Fourcroy Systeme.

[a] Analysis of Brighton Water.

OXALAT OF MAGNESIA.

This acid diſſolves magneſia, and forms a white powder which is inſoluble in water or alcohol unleſs the acid be ſuperabundant. 100 parts of the ſalt are eſtimated by Bergman to contain 35 of magneſia.

OXALAT OF ALUMINE.

Oxalic acid digeſted on clay, diſſolves the alumine, and forms an uncryſtallizable maſs of a ſweetiſh aſtringent taſte: 100 parts contain 44 of alumine.

METALLIC OXALATS.

A few only of theſe require particular notice.

Oxalat of Silver. When oxalic acid or an alkaline oxalat is added to nitrated ſilver in ſolution, a white inſoluble oxalat of ſilver is produced. Sulphat of ſilver is equally precipitated by this acid. Oxalat of ſilver is ſpeedily blackened by the ſun's rays, and in part decompoſed. In this ſtate if heated to redneſs it diſperſes with a ſudden noiſe.

Oxalat of Mercury is formed by adding this acid to any ſolution of the metal. It is a white inſoluble powder, but blackens in the ſun's rays.

Oxalat of Lead. Lead is corroded by this acid, and its oxyd is readily diſſolved, and cryſtallizes by evaporation. The oxalic acid decompoſes the nitrat and acetite of lead, but not the ſulphat, and hence in Scheele's original experiments the ſulphuric acid was uſed to diſengage the oxalic acid from the oxalat of lead formed by adding the ſalt of ſorrel to the acetite of this metal.

Oxalat of Copper. This acid diſſolves copper both metallic and oxidated. The ſalt is ſcarcely ſoluble in water. Moſt of the other ſolutions of this metal are decompoſed by the oxalic acid, and an inſoluble oxalat falls down.

Oxalat of Iron. Iron is readily diſſolved by this acid with copious diſengagement of hydrogen gas. This ſolution gives by concentration greeniſh yellow priſmatic cryſtals, eaſily ſoluble in water. It alſo diſſolves many of the ſalts and oxyds of this metal, and hence its original uſe in removing iron-mould ſpots in linen. When added to the red ſulphat or muriat of this metal, a fine red oxalat of iron is precipitated, ſoluble in an exceſs of the ſame acid.

Moſt of the other metals (gold and platina excepted) are ſoluble in this acid, forming ſalts generally of little ſolubility except with an exceſs of acid.

The ſuper-oxalat of potaſh alſo acts upon iron, copper, and ſeveral other metals, and theſe ſolutions retain the potaſh belonging to the acidulum, and cryſtallize with it into triple ſalts that deſerve further examination.

OXYD.

This term may be properly applied to any ſubſtance chemically combined with oxygen, but it is reſtricted to thoſe that have not acquired acid properties by the combination. It is chiefly uſed to expreſs thoſe modifications of metallic bodies formerly termed *calces*.

OXYGEN GAS. *Dephlogiſticated air* (of Dr. Prieſtley.) *Vital air. Empyreal air* (of Scheele.) *Der Sauerſtoffe.* Germ.

Oxygen is probably the moſt abundant of all natural bodies, and its chemical properties are ſo important that a very large ſhare of the ſcience of chemiſtry conſiſts in a knowledge of the combinations and agency of this body.

There are two immenſe ſources whence oxygen is derived, namely water and air. In the former it is condenſed into the liquid form, and combined with about a third of its weight of hydrogen: in the latter it is united with azot, and forms little more than a fifth of the atmoſphere.

There are beſides other ſmaller ſources of oxygen, ſuch as many parts of the organized world, vegetable or animal, (independent of the water which they contain ſo abundantly,) mineral acids, and metallic oxyds, &c. but the quantity from theſe latter ſources is extremely ſmall in compariſon with the former.

Oxygen when free from all combinations, (that of light and heat excepted) is in the gaſſeous form, and it was firſt obtained by Dr. Prieſtley in the year 1774 from the oxyd of mercury, and the year following it was diſcovered by Scheele, who procured it from the oxyd of mangancſe.

We ſhall not purſue the hiſtory of the diſcoveries relating to this important ſubſtance, but proceed with its properties as now fully aſcertained, and the modes of procuring it.

The pureſt poſſible oxygen gas is obtained by diſtilling *per ſe* the dry *oxymuriat of potaſh.* This ſalt is to be put into a ſmall glaſs retort, and with the heat of an Argand's lamp it melts, and then is decompoſed, giving out an abundance of oxygen gas of great purity, which is to be received over water or mercury in the uſual way. When the heat is raiſed to redneſs, all the oxygen is expelled, and in this way 100 grains of the ſalt will afford about 112 cubic inches* of oxygen of extreme purity. This method however is expenſive, but oxygen

* Chenevix.

pure enough for most experiments may be got much cheaper by other ways.

The black oxyd of manganese contains a great abundance of oxygen so loosely combined as to be expelled by a moderate red heat, and this is the method usually pursued. An earthen or iron retort (the latter of which are made for this express purpose) is to be filled with the black oxyd of manganese in powder, and heated in a brisk fire. The first product of gas comes over when the manganese is faintly red, and consists chiefly of carbonic acid, so that a taper is immediately extinguished. After this if small samples of the gas are examined as it comes over by dipping a bit of kindled wood in it, the fire will soon be found to burn with encreased flame and brightness, a sign of the presence of oxygen, soon after which it may be collected for use. If the manganese be very good, one pound of it (which will lie in a very small retort) will give about 1400 cubic inches of oxygen of great purity, that is, containing perhaps no more than a tenth of carbonic acid or any other gas. The oxygen begins to come over in quantity when the manganese is red-hot, and a full red heat should be continued as long as any gas comes over. The residue is a dark grey oxyd.

Manganese if moistened with sulphuric acid will also give out much oxygen on applying no greater heat than that of a taper, and hence it may be obtained very expeditiously with the simplest apparatus possible. But a great difference is found in this respect in the different species of manganese.

All the oxyds of mercury when heated red hot are decomposed, the metal returns to the state of running mercury, (which is driven up in vapour and soon condenses) and the oxygen which it contained appears in the gasseous form, mixed with any acid, if such existed in the oxyd. Hence the *calcined mercury* or precipitate *per se*, which is a simple combination of oxygen and mercury, when heated in a retort to a low red heat, yields only oxygen gas and mercury in vapour, the whole of the oxyd is decomposed, the mercurial vapour condenses into extremely pure running mercury, and the oxygen gas remains. This was the way in which Dr. Priestley first obtained this gas, and is often practised when a very pure oxygen gas is wanted, as it may be done in a glass retort slightly coated, held over a pan of charcoal so as to heat it to moderate redness. But as the oxyd *per se* is a very expensive preparation, the red nitrous oxyd is usually substituted. (See the articles *Mercury* and *Atmospherical Air*.) These oxyds yield about $\frac{1}{7}$ of their weight of oxygen gas. This gas is however at first a little impregnated with mercurial vapour, which is deposited as a white film on the surface of the water over which the gas should stand for a day.

Turbith mineral (the sulphated oxyd of mercury) yields much oxygen in this way, mixed with some sulphureous acid.

The *Red oxyd of Lead* or *Minium* heated to redness in an earthen retort gives abundance of oxygen, but mixed with some carbonic acid gas.

All the oxyds of iron when heated to full redness begin to give out oxygen in considerable purity.

Oxygen gas may also be obtained very cheap and considerably pure, by the destructive distillation of nitre in a moderate red heat. This process which highly illustrates the decomposition of nitric acid, has been already noticed under the article *Nitrat of Potash*. To obtain oxygen from it, put some dry nitre in a coated glass or an earthen retort, lute a tube to it to convey away the gas to the proper vessels, filled with and inverted over water, and apply a heat gradually raised to redness. When red-hot, the acid of the nitre is decomposed, and a very large quantity of oxygen is given out for a considerable time, till at last all the acid is dissipated in the form of oxygen and azot, and caustic potash remains in the retort, which last if the operation be pushed to the utmost, corrodes the retort and renders it unfit for a second charge. The oxygen is considerably pure in this way, but is mixed with a portion of azot, particularly towards the last. It is obtained simpler and cheaper by substituting to the retort two earthen crucibles, one inverted over the other, and the point of contact between the two well luted, and a tube proceeding from the upper crucible to convey away the gas.[b] Nitrat of soda will answer as well, as will most of the metallic nitrats, and many other substances moistened with nitric acid. Dr. Priestley obtained from 2 oz. of nitre heated in an earthen retort, about 812 oz. measures, and the vessel melted with the alkali before the process was finished.

All the nitrats (nitrated ammonia excepted) will yield oxygen gas when exposed to a heat sufficient to decompose the acid.

Most of the green parts of vegetables while living, yield oxygen gas when exposed to the

[b] An. Chim. Tom. 25. p. 187.

sun's rays. Of these the green conferva of ponds is a remarkable instance, as Dr. Ingenhousz has shewn by experiment.

The specific gravity of oxygen gas according to Kirwan is 0.00135, or 740 times lighter than water, (at 30 inches bar. and 60° therm). and it is heavier than common air in the proportion of 1103 to 1000. The weight one hundred cubic inches of it is equal to 34 grains; but Mr. Davy makes it 35.06. The expansion or contraction which it undergoes by changes in pressure and temperature, will be given in the appendix.

This gas is only in a very small degree absorbed by water. According to Mr. Henry's experiments, 100 cubic inches of well boiled water absorb 3.55 of oxygen. This solution has no particular sensible qualities.

The characters that peculiarly distinguish oxygen gas, are the eminent degree in which it supports combustion and respiration; and it is proved that neither of these can go on without oxygen, and that it is solely owing to its presence that atmospheric air and the other compound gasses are fitted for maintaining these grand processes of the material world. The function of respiration will not be treated of in this work, it may therefore be merely mentioned in this place, that if a small animal is immersed in oxygen gas, it will live much longer than in the same quantity of common air, and if the carbonic generated in the process be occasionally removed by alkalies, the animal will remain in the gas uninjured for a much greater length of time. In this and in many other respects the processes of respiration and combustion agree, but still there are some circumstances which render it probable that the diluter state of oxygen, (such as it exists in common air) is altogether *fitter* for animal respiration than a purer oxygen.

The burning of the several combustible bodies in oxygen gas, forms a number of most beautiful and instructive experiments, and has contributed more than any thing else to give accurate ideas on the nature of combustion in general. Some of the experiments are the following:

Immerse a lighted taper in the gas, and it will burn with a prodigious encrease of rapidity, and a dazzling light.

Heat the top of a bit of charcoal red-hot, (which if merely left in the open air will soon be covered with a white ash, and be extinguished); introduce it into oxygen gas, and the kindled part will suddenly glow with a bright heat, and emission of brilliant sparks for a certain time, after which it will go out. The bulk of the remaining gas is not much altered, but a large quantity of the oxygen will be consumed, and in its stead much *carbonic acid gas* will be generated, which will instantly render lime water milky when shaken with it, and may be removed by lime or alkalies. The weight of carbonic acid will be found to equal the loss sustained by the charcoal and by the oxygen united.

Introduce a small piece of phosphorus into a large jar of oxygen, with an atom of lighted tinder in contact with it. (The best apparatus for these experiments will be mentioned in the appendix.) The phosphorus will burn with a vast body of bright light, so brilliant that the eye can hardly support it, and with intense heat and rapid emission of white fumes. The heat at first expands the gas, and if the jar is quite full throws part of it out, but presently there is a rapid absorption, the water being sucked up into the jar, and if the gas were quite pure none would be left. The white vapours are *phosphoric acid*, the product of the combustion, and obviously compounded of phosphorus and oxygen, as in the former experiment the carbonic acid gas was produced by the union of charcoal and oxygen.

Provide a bottle with a cork perforated to admit a glass tube drawn out to a tolerably fine point, and bent at right angles in the middle. Fill the bottle nearly full with very dilute sulphuric or muriatic acid, and throw in several small bits of zinc. This will produce a copious stream of hydrogen gas, which (when it has run to waste for a short time to expel the common air of the bottle) kindle at the end of the glass tube, and immediately introduce it into the side opening of a small tubulated receiver, full of oxygen, through the perforation of a cork cut to fit exactly, whilst the neck of the receiver is inverted over water. The stream of hydrogen will burn with an enlarged flame, and without any smoke, and all the inside of the receiver will be covered with a watery dew. The gas will gradually disappear and the water rise. In this process (and others more accurate will be mentioned under the article *Water*) the sole product is water, which therefore is produced by the union of hydrogen and oxygen at a high temperature.

Make a spiral coil of iron wire, and kindle it, and introduce it into oxygen gas. (The manner of performing the experiment is described under the article *Iron*, and in the Appendix). After a most brilliant combustion the iron will

be melted in drops at the bottom of the veſſel, and converted into an *Oxyd of Iron*.

The above are only a few of a number of beautiful experiments which have been deviſed, to ſhew the rapidity with which bodies burn in oxygen gas, and the products of ſuch combuſtion.

The proceſs of combuſtion, which is one of the moſt ſtriking and moſt familiar of all the natural phenomena, has long engaged the utmoſt attention of philoſophers. It is not our intention, in a work like the preſent, which chiefly aims at collecting and recording facts and familiar proceſſes, to give any hiſtory of the theories that have been advanced on this curious and difficult ſubject. It will be ſufficient to obſerve that there have been at leaſt three hypotheſes made to account for combuſtion, together with ſeveral modifications of each. The firſt in order of time is the *Phlogiſtic* theory, which was brought to a very ingenious ſyſtem by Stahl, who is generally looked upon as its author. This able philoſopher ſuppoſes that all inflammable bodies (or ſuch as *burn* with emiſſion of light and heat) contain a portion of an intangible, imponderable principle, called phlogiſton, to which they owe their inflammability with all its attendant phenomena. Whilſt a body is burning, it parts with its phlogiſton, which paſſes into combination with the ambient air, and it is thus reduced for the moſt part into an aſh, or (if a metal) into a calx, which differs from the original ſubſtance only in being deprived of phlogiſton. Therefore (to take a metal as an example) in order to reduce the *calx* to the metallic ſtate, it is neceſſary to unite it with ſome inflammable ſubſtance, ſuch as charcoal, which reſtores its phlogiſton, and brings it back to the metallic or reguline ſtate.

But this ingenious hypotheſis was made before the diſcovery of oxygen, and before the preciſe agency of air in maintaining combuſtion was underſtood, and therefore the ſeveral modifications made to accommodate it to all the then known chemical facts, were all eſſentially defective.

The diſcovery of oxygen by Dr. Prieſtley, followed at no great length of time, which gave riſe to the moſt admirable and beautiful reſearches of Lavoiſier, on the ſubject of combuſtion, in which this excellent philoſopher demonſtrated that in all caſes of combuſtion, the inflammable ſubſtance united with oxygen, and produced either an acid, or an oxyd, or water, or a mixture of theſe three, and the weight of the product above that of the ſimple combuſtible was exactly equal to the quantity of oxygen which had diſappeared. In this reſpect therefore the ſyſtem ſo finely brought out by Lavoiſier was not ſo much an improvement of Stahl's, as an eſſential addition to it and all other previous theories, by accounting for the increaſe of weight of the *product* of combuſtion over that of the combuſtible. But *combuſtion* implies the diſengagement of light and heat, which was ſtill to be explained, and this was done by Lavoiſier, to the utter excluſion of phlogiſton (the exiſtence of which was at all times very problematical) by ſuppoſing oxygen gas to be a compound of oxygen with heat and light, and therefore whilſt a body *burns* (according to Lavoiſier) it abſorbs oxygen from the air, ſeparating it from the heat and light with which it was united, and which then appear in the ſenſible form of *fire*. This ſyſtem therefore allows of no other difference between combuſtion and ſlow oxygenation, than that in the former caſe, the proceſs going rapidly, the heat and light ſeparated from the oxygen gas appear in the form of viſible flame, and in the latter they eſcape ſlowly and imperceptibly to the ſenſes.

From the way in which Lavoiſier expreſſes himſelf however, it might be ſuppoſed, that he conceived that the only portion of caloric which could be ſet free during combuſtion, was that which is eſſential to the gaſeous form, or that which makes the ſole difference between a ſolid body and the ſame body gaſſified, analogous to the difference in this reſpect between ſteam and fluid water. Hence it would follow that no oxygen in ſolid or liquid combination could maintain combuſtion, a poſition which is inſtantly refuted by the well-known power of the ſolid oxygen of nitre and oxymuriat of potaſh to inflame charcoal, or the liquid oxygen of nitric acid to kindle eſſential oils.

If therefore oxygen is the ſource of the heat diſengaged during combuſtion (which is extremely probable) it muſt be allowed in ſeveral inſtances to carry the greater part of its heat with it into various combinations, ſo that the oxygen of nitric acid which can ſupport combuſtion, muſt be allowed to be different from that of water (for example) which cannot; and nitric acid therefore muſt be called a compound of azot, and *oxygen with its caloric*; and water a compound of hydrogen and *oxygen without its caloric*. This diſtinction has been well pointed out by Brugnatelli, * who terms the former ſtate *thermoxygen*, and the latter ſimply *oxygen*.

It is a preſumptive argument too, that the

* Journ. de Phyſ. tom. 53.

heat given out during combustion is chiefly derived from the oxygen, that the increase of temperature is generally pretty accurately proportioned to the quantity of oxygen consumed, as was found by Messrs. Lavoisier and La Place, in their experiments with the *calorimeter*.

Several objections of weight however oppose the hypothesis that *light* is also a constituent part of oxygen gas, or of oxygen in any state fit to support combustion. One of the strongest is, that the quantity of light given out in this process, is *not* proportioned to the quantity of heat, and the circumstance of the various colour which the flame assumes, according to the nature of the combustible body, would seem rather to indicate that it is this latter, and not the oxygen gas, which is the principal source of the light.

This opinion has been adopted by several chemists of late years, among whom are Gren and Brugnatelli, and Dr. Thomson. So that according to this system the process of combustion is in fact a double decomposition, in which the combustible body unites with oxygen to form an oxyd, or water, or an acid, according to circumstances, whilst the light of the combustible combines with the caloric of the oxygen, and produces the flame or fire

It will be easily seen that this system in one part bears a resemblance to the ancient hypothesis of phlogiston, insomuch that both of them suppose a something to be contributed by the combustible body itself towards the composition of the *fire or flame*, and this too appears on the whole more consonant with the general phenomena of combustion and oxygenation; but still there remain a vast number of difficulties to be cleared up before it can be fully admitted.

The latest, the most laboured, and certainly one of the most ingenious theories of combustion, is that of Dr. Thompson, who adopts the above-mentioned modification of the phlogistic system, and has given a very satisfactory view of the actual phenomena as far as they are known, to which we shall refer the reader.[b]

OXYMURIATIC ACID.[a] *Acide muriatique oxygéné*. Fr. *Oxygenisirte Salzsäure*. Germ. *Dephlogisticated Marine Acid* of Scheele.

This acid was first discovered by Scheele in consequence of digesting the black oxyd of manganese with muriatic acid. It is best prepared in the following way. Charge a long-necked tubulated glass retort not more than one-fourth full of 8 parts, by weight, of muriated soda, and 3 parts of black oxyd of manganese, these ingredients being in fine powder, and accurately mixed together; then add 5 parts of sulphuric acid, diluted with 4 parts of water: the beak of the retort being now introduced into a common water bath filled with warm water, and a gentle heat being communicated to the ingredients by means of a lamp, a speedy effervescence will take place, the common air will be driven out of the retort by a light yellow coloured gas, which is oxymuriatic acid, and may be collected in inverted vials in the usual manner. The *rationale* of the process is this: sulphuric acid when heated with black oxyd of manganese, drives off part of its oxygen, and then forms with the remaining sub-oxyd sulphat of manganese: muriat of soda is also decomposed by sulphuric acid, the muriatic acid being separated by the superior affinity of the sulphuric. But if these two distinct decompositions take place at the same time and in the same vessel, the oxygen and muriatic acid gasses while in a nascent state, combine together producing a new compound, oxymuriatic gas, which being but little soluble in warm water, is collected as we have just described; any portion of common muriatic acid that might be accidentally mixed with it being compleatly separated by means of the water through which it passes. This gas may also be procured in a more simple, though not quite so eligible a manner, by digesting strong muriatic acid with about half its weight of black oxyd of manganese.

Oxymuriatic acid gas is of a light yellowish green colour: its specific gravity has not been ascertained. Its odour is more penetrating and suffocating than even that of sulphureous acid, occasioning a long-continued and convulsive cough, even when largely mixed with common air; when pure, or nearly so, it is instantaneously fatal to animal life. A cubic inch of water at 43° Fahr. is capable of absorbing 1.07 grains troy of this gas, and thereby acquires a density of 1.003: but though cold water takes up this gas without much difficulty, it is nearly insoluble in hot water: hence the best method of obtaining the liquid acid is by means of a Woulfe's apparatus, the bottles of which are surrounded with ice; by this management, when the water is nearly saturated with the gas, it deposits thin lamellar crystals of oxymuriatic acid, which again dissolve and mix with the rest of the fluid on a small increase of temperature; and at a higher heat, part of the acid escapes in an elastic form.

[b] System of Chemistry and Phil. Journ. 8vo Vol. 2.

[a] Berthollet, Chem. statique. II.

Both in colour and odour the liquid acid is similar to, but weaker than the gas, to the taste it is austere and somewhat acrid, but not sour. It differs from other acids in entirely discharging all vegetable colours except charcoal black, nor are they capable of being restored by the subsequent application of an alkali. The same effects are produced by the gasseous acid, but if this in a concentrated state is allowed to remain long in contact with vegetable fibre, it weakens its texture, and turns it first to yellow and at length brown, by carrying off the hydrogen and reducing the carbon nearly to the state of charcoal. The colour is in like manner discharged from animal fibre, but the destructive action of the acid on the fibre taking place at the same time, a yellow colour is evolved, which no after process can get rid of. Thus if a mixed stuff of linen and woollen be dyed with indigo, and afterwards submitted to the action of either the gasseous or liquid acid, the blue colour will be found in the course of an hour or two to be destroyed, and the fibres of the linen will appear white, and those of the wool yellow.

Oxymuriatic acid gas, though fatal to animal life, is in many cases capable of supporting combustion: a lighted taper if plunged suddenly in it, is often extinguished, but if let down gently it continues to burn with a remarkably red, but somewhat diminished flame, and a very copious smoke, being at the same time consumed with uncommon rapidity. Light appears to have no effect on this gas, and it may be passed through a red hot earthen or glass tube without any change, except a temporary increase in bulk. The liquid acid on the contrary, undergoes a decomposition by the action of light, oxygen gas being evolved, and the acid returning, for the most part at least, to the state of common muriatic: whence the necessity of keeping it in an opake bottle, or in a dark closet.

Oxymuriatic acid gas, when mixed with hydrogen and passed through a red hot earthen tube, is rapidly decomposed, inflammation and detonation being the consequence, a similar effect takes place if a lighted match is applied to the mixed gasses; but at the usual temperature the mutual action of these two gasses is very slow; at length however the oxygen of the acid gas combines with the hydrogen, and liquid muriatic acid is the result.

Sulphur at the common temperature slowly decomposes oxymuriatic acid gas, and is itself partly acidified; but if melted sulphur is introduced into a jar full of the gas, an immediate inflammation takes place, and sulphuric acid is formed. The liquid acid has no action on sulphur.

Sulphuretted hydrogen and oxymuriatic acid gas mutually decompose each other, but without inflammation; if the latter is less in quantity than the former the hydrogen only of the sulphuret is oxygenated, but if the acid is considerably in excess, both the hydrogen and sulphur are oxygenated, and the products are muriatic and sulphuric acids and water. An analogous effect takes place if the acid and hydro-sulphuret are employed liquid instead of gasseous. When the acid is poured by successive small portions into the hydro-sulphuret, this latter is decomposed, and its sulphur is precipitated: but if this is reversed, and the hydro-sulphuret is poured into the acid, no precipitation takes place, the sulphur being acidified.

Phosphorus, if cut into small pieces and dried in blotting paper, deflagrates with a bright flame as soon as it is introduced into oxymuriatic acid gas, the oxygen being at the same time transferred from the acid to the phosphorus. This combustible body has no action on the liquid acid, except it is assisted by a strong light: in this case the oxygen, as it quits the oxymuriatic acid, unites slowly and silently with the phosphorus, which is thus acidified.

Phosphuretted hydrogen readily decomposes the gasseous acid, a flame (not however so bright as when oxygen gas is employed) making its appearance at the instant of their union. If the acid and phosphuret are mixed together in a liquid state, the decomposition happens with precisely the same modifications as we have just described with regard to liquid hydrosulphuret. Phosphorized essential oil, by remaining a few minutes in this acid gas, becomes considerably heated, but does not inflame, if however in this state it be removed into the common air, it takes fire with a kind of explosion. [b]

All the metals decompose oxymuriatic acid gas, and many of them, if sufficiently attenuated, undergo actual inflammation. Thus if a leaf of gold or copper be let down into a wide-mouthed vial full of this gas, the metal will burn with a green light, will be oxydated, and will then combine with the muriatic acid with which it finds itself in contact. Several of the metals, such as antimony, arsenic, bismuth, and tin, when reduced to a fine powder and poured

[b] Pickel, in Ann. de Chem. xiii. p. 223.

into the gas, become immediately red hot, and present the appearance of a shower of fire. Some of the metallic sulphurets, especially those of mercury, antimony, and arsenic, in like manner decompose this gas, being themselves ignited and oxygenated.

The liquid oxymuriatic acid is decomposed by all the metals, and the resulting salt is a muriat, the base of which is at a high degree of oxydation. None of the metals during their solution in this acid give out hydrogen, as they do when acted on by simple muriatic acid, for the oxygen which in this latter case they obtain from the decomposition of part of the water, is procured in the former case by the decomposition of the acid.

From the very small difference between the specific gravities of water and liquid oxymuriatic acid, it is obvious that the proper acid part of the fluid is in a state of but little condensation, hence it appears that in this form it is incapable of dislodging the carbonic acid from carbonat of lime, and probably from any other of the perfectly neutralized alkaline carbonats, except perhaps carbonat of ammonia. If therefore some finely pulverized calcareous spar be digested in liquid oxymuriatic acid, it will be found to dissolve in this fluid without the disengagement of a single bubble of carbonic acid: in proportion as it becomes charged with this earthy carbonat, its yellow colour disappears, and its peculiar odour becomes less and less perceptible. On the addition of lime-water or a solution of caustic potash, the carbonat of lime is precipitated unaltered.

The action of ammonia upon oxymuriatic acid gas is very remarkable. If a strong glass jar filled with 18 or 20 cubic inches of the latter substance, be placed in a mercurial bath, and two or three cubic inches of ammoniacal gas are thrown up into the jar, a pretty considerable detonation accompanied by a white light and absorption takes place, and a thick vapour is produced; in a short time the vapour condenses into a fluid consisting of water, muriatic acid, and a little ammonia, and the gas remaining in the jar will be found to be nearly pure azot. Hence it is manifest what happens during this process: the greater part of the ammonia is decomposed into its elements azot and hydrogen, of which the former assumes the elastic state, while the latter reacts on the oxymuriatic acid, deprives it of its oxygen with which it combines to form water, which, as soon as produced, unites with the muriatic acid and undecomposed ammonia, thus composing a watery solution of acidulous ammoniacal muriat.

The precise mode in which the fixed alkalies act on oxymuriatic acid is a subject on which chemists are not yet perfectly agreed. Those who have paid the most attention to this intricate subject are Berthollet and Chenevix, from whose experiments we shall select the following particulars, beginning with those of the last mentioned chemist.

The bottles of a Woulfe's apparatus were charged, the first with a solution of pure potash in six parts of water, the second with a solution of pure potash in about twenty parts of water, and the third with a solution of common carbonat of potash: the third bottle was connected with a pneumatic apparatus, and the first with a retort charged with muriat of soda, sulphuric acid, and black oxyd of manganese, in the usual proportions. By a gentle heat oxymuriatic acid gas was liberated in abundance, and passed into the first bottle, where it was absorbed by the alkali; when this was saturated the acid gas began to combine with the potash of the second bottle, any muriatic or sulphuric acid that might casually rise from the retort along with it, being detained by the alkali of the first. By this management nothing but pure oxymuriatic acid was brought into contact with the potash in the second bottle, and the process was continued till the liquor showed an excess of acid. A portion of this liquor was distilled to dryness in a glass retort, care being taken to prevent the access of light: during this process nothing came over except water and a little of the dilated air of the vessels, it is manifest therefore that the dry salt thus obtained held all the oxygen that had been contained in the oxymuriatic acid, which had combined with the potash in the second bottle of the Woulfe's apparatus. 100 grains of this dry salt were then dissolved in water, and by the addition of nitrat of silver a quantity of muriated silver was precipitated, indicative of 84 parts of muriated potash: but in this salt the acid is not oxygenated, hence it follows that the remaining 16 parts not decomposable by nitrated silver, were *hyper-oxymuriat of potash*, the acid of which was combined with all the oxygen formerly united with that of the 84 parts of muriated potash, and therefore at a much higher degree of oxygenation than common oxymuriatic acid. Hence it appears that the effect of liquid potash on oxymuriatic acid is to decompose it by transferring the whole of its oxygen to a

[a] Chenevix in Phil. Trans. 1802, p. 131.

ſmall part of the acid, and thus reducing the remainder to the ſtate of common muriatic. That this change is entirely compleated almoſt immediately upon the alkali and oxymuriatic acid coming in contact with each other, is proved according to Mr. Chenevix by the following experiment. He decompoſed by nitrat of ſilver 400 grains of the liquor prepared in the ſecond Woulfe bottle, and obtained 71 grains of muriated ſilver. A like quantity of the liquor was then gradually evaporated to dryneſs, and the reſidual ſalt again diſſolved in water; from this, nitrat of ſilver threw down 70 grs. of muriat. Now if in the former caſe any of the acid had been in the ſtate of oxymuriatic, the amount of hyper-oxymuriatic and muriatic acids would have been proportionably diminiſhed, and alſo of courſe the precipitate of muriated ſilver. Thus as appears from the experiments and reaſoning of Mr. Chenevix, when cauſtic potaſh is ſaturated by oxymuriatic acid gas, an immediate decompoſition of this laſt takes place, no oxymuriat of potaſh is formed, but ſimple muriat and hyper-oxymuriat in the proportion of 84 of the former to 16 of the latter.

But ſome doubts as to the legitimacy of the concluſions deduced by Mr. C. from his experiments have been ſuggeſted by M. Berthollet, which we ſhall now proceed to ſtate. And firſt as to the proof by nitrated ſilver: this according to the able chemiſt juſt mentioned, is not in this caſe to be depended on, ſince the affinity of the oxyd of ſilver for muriatic acid may itſelf determine the transfer of oxygen neceſſary to the production of hyper-oxymuriatic acid. As a further proof that the decompoſition of the oxymuriatic acid into common muriatic and hyper-oxymuriatic acids is a much more gradual proceſs than it is ſuppoſed to be by Mr. Chenevix, the following experiment was made by M. Berthollet.[d] Into a ſolution of potaſh a quantity of oxymuriatic acid gas was paſſed, not quite ſufficient to ſaturate the alkali: the reſulting fluid was divided into two equal portions, of which one was immediately expoſed to the action of light, and the other was kept in the dark for a fortnight, and then ſet in the ſunſhine. Now it is the effect of light to decompoſe the oxymuriatic acid, but not the hyper-oxymuriatic, by liberating its oxygen, hence if the decompoſition of the former had been immediate and total on its experiencing the action of the alkali, no oxygen gas ought to have been produced, but in fact the former portion of liquor afforded 16 parts, and the latter portion 7 parts of this gas, whence it follows, firſt, that the decompoſition of the oxymuriatic acid by means of potaſh is only partial, and ſecondly that it is not inſtantaneous. A further proof of the correctneſs of this repreſentation is that the liquor in queſtion retained the property of diſcharging vegetable colours, which is characteriſtic of the oxymuriatic, but not of the hyper-oxymuriatic acid. A remark by Mr. Hoyle[e] may be brought in further confirmation of M. Berthollet's theory, namely, that after ſeparating the hyper-oxymuriat of potaſh from the liquor in the form of cryſtalline plates and needles by refrigeration, there was obtained by evaporation a muriat of potaſh, conſiderably oxygenated, though not capable of detonating with ſulphur, and therefore not in the ſtate of hyper-oxymuriat.

Some further experiments of M. Berthollet have alſo confirmed a former obſervation made by him, and afterwards called in queſtion by Mr. Chenevix, which is, that if oxymuriatic acid gas be paſſed into a ſomewhat concentrated ſolution of potaſh, the affinity of this laſt for muriatic acid becomes ſo powerful as to decompoſe it at a greater rate than hyper-oxymuriat of potaſh can be formed, in conſequence of which an actual diſengagement of oxygen gas takes place, and as the experiment ſucceeds perfectly well in the dark, it is obvious that the action of light has nothing to do in this caſe.

The proportions of the ingredients of oxymuriatic acid were firſt ſtated by Berthollet at

89	Muriatic acid
11	Oxygen
100	

The mode by which he obtained this reſult, though very ſimple, was not however quite correct. He ſaturated with the acid gas 50 cubic inches of water and expoſed it to the ſun till it ceaſed to give out oxygen gas: the quantity of this latter thus procured, amounted to 8 grs. and the reſidual liquor by the teſt of nitrated ſilver indicated 65 grs. of muriatic acid. Hence : 73 : 8 :: 100 : 11 nearly. But M. Berthollet himſelf is of opinion that the whole of the oxygen was not ſeparated from the liquor by the action of light, and has acquieſced in the proportions laid down by Mr. Chenevix according to the following method of analyſis. Having ſlightly ſuperſaturated a ſolution of potaſh by paſſing oxymuriatic acid

[d] Chim. Stat. §. 317.

[e] Mancheſter Phil. Tranſ. V. p. 226.

gas into it, he evaporated the liquor to drynefs and then rediffolved 100 parts of the falt in water; then by the teft of nitrat of filver he afcertained the prefence of 84 parts of muriated potafh, (confifting of 27.88 muriatic acid and 56.12 potafh) and 16 parts of hyper-oxymuriat of potafh (confifting of 9 parts oxygen, 3.2 muriatic acid, and 3.8 potafh). Hence (27.88 + 3.2) = 31.2 muriatic acid + 9 oxygen = 40.2 oxymuriatic acid: therefore this acid is compofed of

84	muriatic acid
16	Oxygen
100	

Although there feems little reafon to doubt the exiftence of the clafs of proper oxymuriats, yet they have not as yet been the fubject of chemical inveftigation.

HYPEROXYMURIATIC ACID.

This acid exifts in the alkaline, earthy and metallic hyper-oxymuriats, but cannot be difengaged except in a ftate of greater or lefs decompofition by any means that have hitherto been attempted. On account of the large proportion of oxygen which it contains, the effects produced by it on combuftible fubftances are much more rapid and violent than thofe occafioned by oxymuriatic acid. It is compofed according to Mr. Chenevix, whofe experiments on this fubject will be mentioned in the next article, of

35	Muriatic acid
65	Oxygen
100	

The order of its affinities as afcertained by Mr. Chenevix is, potafh, foda, barytes, ftrontian, lime, ammonia, magnefia, alumine.

Hyperoxymuriat of Potash. Common oxymuriat of potafh.

This falt is beft prepared by charging one or two Woulfe bottles with a moderately ftrong folution of femi cauftic potafh (purified pearlafh) and then throwing in oxymuriatic acid gas from a mixture of common falt, black oxyd of manganefe and fulphuric acid: when the alkali is nearly faturated, an effervefcence for the moft part of carbonic acid, makes its appearance, and thin faline fcales begin to be precipitated: after the effervefcence has ceafed, the contents of the bottles may be poured into a wide mouthed flafk and fet for a few hours in a dark cold place; a confiderable quantity of cryftalline plates will be thus depofited, which are hyperoxymuriat of potafh. Thefe being taken out of the liquor and drained are to be rediffolved in hot water, which by cooling will depofit the greater part of the falt, and generally a little earthy matter, which is oxyd of manganefe; and this is finally to be got rid of by re-folution and cryftallization.

The falt thus obtained is in the form of thin glittering fcales, of a pure filvery white colour not unlike boracic acid, but if the mother water of the laft cryftallization is expofed to fpontaneous evaporation, its falt will be depofited in fhort obtufe rhomboidal prifms.

It is inodorous. To the tafte it is cooling and fomewhat pungent and auftere: it has been compared in this refpect to nitre, from which however it is very fenfibly different. Its fp. gr. is 1.98. It crackles and emits fparks of light when rubbed brifkly in a mortar. It is foluble in 16 or 17 parts of water at 60°, and in two and a half parts of boiling water; alcohol is alfo capable of taking up a fmall portion. Neither the dry falt nor its aqueous folution are in the leaft affected by expofure to the light. When expofed to the air it becomes fomewhat damp in moift weather, and at length acquires a flightly yellow tinge.

When heated by a lamp this falt decrepitates gently, and then melts and lofes about two *per cent.* being chiefly water of cryftallization; if heated to rednefs it is rapidly decompofed, a torrent of pure oxygen gas being given out, and the falt is converted into muriat of potafh: from 100 parts thus treated, and further decompofed by nitrat of filver, Mr. Chenevix obtained

20	Muriatic acid
38.3	Oxygen
39.2	Potafh
2.5	Water
100.0	

The action of fulphuric acid upon hyperoxymuriat of potafh is very remarkable: if fome of the concentrated acid be poured upon this falt a violent decrepitation, fometimes accompanied by a flafh, takes place, and a thick heavy vapour of a greenifh yellow colour is difengaged. The fmell of this vapour refembles that of a mixture of nitrous gas with that emitted from burning brick-kilns, hence it is very different from the odour of oxymuriatic acid, neither is it by any means fo fuffocating and oppreffive to the lungs. Beneath this vapour is a bright orange coloured liquor which has the fame

odour as the vapour. This liquor is a mixture of sulphuric acid, potash, and hyperoxymuriatic acid, not indeed so pure as when combined with the potash but mingled more or less with muriatic and oxymuriatic acids. If this mixture of hyper oxymuriat of potash and sulphuric acid be heated over a lamp or in any other way, by the time that it has acquired the temperature of 125° or thereabouts, an exceedingly loud explosion accompanied by a white and vivid flash takes place, breaking the vessel in which the mixture is contained, and dispersing its fragments with great violence in every direction. If the sulphuric acid instead of being concentrated is diluted with twice or thrice its weight of water, and the beak of the retort containing the materials is dipped in a bason of water with an inverted jar of the same placed over it, there will happen a rapid disengagement of a yellowish gas without risk of explosion on the application of a lighted lamp. This gas when it enters the water of the jar will be in part absorbed, forming a weak liquid oxymuriatic acid mixed with common muriatic acid, and the unabsorbed portion will be found to be oxygen gas. Hence it is evident that hyperoxymuriatic acid cannot be separated from its combination with potash by either strong or weak sulphuric acid, without at the same time undergoing decomposition.

Nitric acid produces nearly the same phenomena with this salt, but in a less marked and distinct manner.

Muriatic acid decomposes this salt, but neither the yellow vapour nor the orange-coloured liquor are produced: by the application of a gentle heat an acid gas is liberated which, although not hyperoxymuriatic acid, is considerably more oxygenated than oxymuriatic acid: the composition of this gas is however by no means uniform, depending very materially on the quantity of muriatic acid employed beyond what is absolutely necessary to the saturation of the alkali. The oxymuriatic gas made use of by Mr. Cruickshank, in his analysis of the hydrocarbonats, was thus procured, and consisted of 56.5 muriatic acid, and 43.5 oxygen.

Oxalic, tartareous, and citric acids, are also capable of decomposing this salt, but the acid gas that is liberated is less oxygenated than when any of the three mineral acids is made use of. Phosphoric and arsenic acids exert no action on this salt except by the assistance of heat, in which case much oxygen gas is evolved, and consequently the acid is less oxygenated.

The acid disengaged from hyperoxymuriat of potash by sulphuric or nitric acids, affects combustible substances in the same manner as common oxymuriatic acid gas does, only with more violence and rapidity, on account of its containing a much larger proportion of oxygen. Thus if a grain of phosphorus at the end of a piece of wire be let down into this acid vapour, it immediately bursts into flame, with decrepitation, and a kind of explosion: so in like manner if a few grains of the hyperoxymuriat of potash be put into a wine-glass, and twice the weight of strong sulphuric acid be added, and after that a little alcohol, ether, or oil of turpentine be poured in, an immediate and rapid inflammation will take place; the same effect happens with many of the readily combustible solids, particularly camphor, rosin, tallow, pitch, and caoutchouc.

So powerful is the action of this highly oxygenized acid, that it is not destroyed even by the presence of water, though it is in some degree impeded and modified. Hence arises a considerable variety of interesting and very beautiful experiments, from which we shall select the two following:[s] 1. Take a long ale-glass, put into it a few grains of hyperoxymuriat, and then pour in water to the depth of from two to three inches; upon the surface of this fluid drop in a little expressed vegetable oil, and then by means of a long slender funnel, with its stem resting at the bottom of the glass, pour in four or five times as much strong sulphuric acid as had been previously added of salt, and immediately after withdraw the funnel: the acid and salt will presently react on each other, highly oxygenized muriatic acid gas will be liberated, which, passing through the water, enters the oil, and immediately converts it to a black frothy fluid, a multitude of ignited sparks being disengaged at the same time. 2. Take about ten grains of phosphorus and cut it, under water, into very small pieces, then put 20 grains of hyperoxymuriat into a glass jar nine or ten inches long, and pour in water sufficient to half fill it; drop in the phosphorus, and then add 40 or 50 grains of strong sulphuric acid, by means of a long funnel, as described above. As soon as the hyperoxymuriat begins to be decomposed, the phosphorus takes fire, and burns vividly at the bottom of the vessel: on agitating the mixture, streams of fire pass rapidly to the surface. This experiment requires some precaution, for the phosphorus is occasionally thrown out of the vessel in a state of

[s] Nicholson's Journ. 8vo. I. p. 297.

ignition, more especially when a common wine-glass is used instead of a jar.

So easily is this hyperoxymuriat decomposed, that when simply rubbed in a mortar with various combustible bodies, it detonates with them more or less forcibly: this we believe was first ascertained by Mr. Hoyle,[a] and nearly about the same time by Vauquelin and Fourcroy. We shall select some of the most striking instances. Half a grain of phosphorus and an equal quantity of the salt, explode almost immediately, with a violent report and a bright flash. Two grains of the salt and 1 of very finely pulverized and dry charcoal, produce by a smart stroke a strong flame, without much report. Half a grain of dry pit-coal and 1 grain of salt, produce sparks and considerable reports. One grain of the salt and three-fourths of a grain of sulphur, produce one very loud explosion; when the sulphur is reduced to a quarter of a grain, there are produced by a long smart stroke with the pestle, several small successive explosions. One grain of the salt and an equal weight of alkaline sulphuret, produce a very loud explosion with flame; it is remarkable however that this mixture, when melted over the fire, merely emits a flash without any report, in which it differs materially from the fulminating powder made with nitre and sulphuret. One grain of white sugar and 2 of the salt, produce a number of successive reports, like the loud crack of a whip. A similar effect is occasioned by rubbing a few grains of the salt with as many drops of spermaceti oil, olive oil, and various essential oils, particularly oil of turpentine, also with camphor, rosin, or indigo. If sulphuric acid is poured on any of the foregoing mixtures previous to detonation, a copious flame, but without much noise, is emitted. The loudness of the explosion in the above cases is materially influenced by the degree of friction, hence if the ingredients, after being thoroughly mixed by slight friction in the mortar not sufficient to produce decomposition (which may be effected in all cases except when phosphorus is employed) are then wrapped in a piece of tin-foil, and struck on an anvil with a cold and heavy hammer, the violence of the explosion will be remarkably increased, and several substances may be thus inflamed, which remain unaltered when simple friction is had recourse to; such are cotton wool, certain of the metallic sulphurets, and almost all the metals.

Hyperoxymuriat of potash is chiefly used in the laboratory, where it is employed in the preparation of the purest oxygen gas. A few grains of it stirred into an ounce of common muriatic acid, form a useful extemporaneous bleaching liquor, for various purposes. It has been attempted in France to compose a gunpowder of this salt, instead of nitre, but without success; the mixture exploded while it was grinding, and killed two persons who were standing near.

Hyperoxymuriat of Soda.[a]

This salt is prepared in the same manner as the former, by substituting soda for potash, and with the same phenomena. It is very difficult to obtain it pure on account of its solubility in water being little different from that of muriat of soda. It is soluble in three parts of cold, and somewhat less of boiling water, and is slightly deliquescent. It is also soluble in alcohol, and appears to render muriat of soda also soluble in the same menstruum. By repeated solutions and crystallizations in alcohol it may however be obtained (though with great difficulty) in a state of purity. It crystallizes in cubes, and produces a sensation of cold in the mouth. It is decomposable with decomposition of the acid by the same substances and in the same manner as the former species. Its base is abstracted only by potash. It is composed of

66.2	Hyperoxymuriatic acid
29.6	Soda
4.2	Water
100.0	

It is made no use of.

Hyperoxymuriat of Barytes.[a]

The earthy hyperoxymuriats are not so easily prepared as the alkaline ores, on account of the inferior affinity subsisting between their ingredients, and the inferior solubility of the bases. To prepare the present salt the Woulfe bottles should be charged with pure barytes, diffused in warm water, and a current of oxymuriatic acid gas should be passed through the liquor till compleat saturation. This salt is soluble in four parts of cold and a quantity of warm water. It crystallizes like the muriat of barytes and can only be obtained pure by boiling the entire liquor with phosphat of silver dissolved in distilled vinegar; the muriat of barytes and phosphat of silver mutually decompose each other, and form two insoluble salts, while the hyperoxymuriat is not affected. This salt has the same properties as the preceding, and is composed of.

[a] Manchester Phil. Trans. V. p. 233. [a] Chenevix, in Phil. Trans. [a] Chenevix.

47. Hyperoxymuriatic acid
42.2 Barytes
10.8 Water

100.0

It is not used.

HYPEROXYMURIAT OF STRONTIAN.*

This salt is prepared in the same manner as the foregoing, and is separated, like that, from the simple muriat by phosphat of silver. It crystallizes in needles, is deliquescent, and is more soluble in alcohol than the muriat of strontian. It melts in the mouth immediately, and produces cold. It is composed of

46. Hyperoxymuriatic acid
26. Strontian
28. Water

100

It is not used.

HYPEROXYMURIAT OF LIME.

This salt is obtained pure in the manner already described. It is extremely deliquescent, and melts at a very gentle heat in its water of crystallization. It is very soluble in alcohol, has a sharp bitter taste, and produces much cold in the mouth. It consists of

55.2 Hyperoxymuriatic acid
28.3 Lime
16.5 Water

100.0

Although the pure salt is not made use of, yet the entire liquor formed by saturating a very thick milk of lime with oxymuriatic acid gas, is extensively employed as a bleaching material by the callico printers. It is said to bleach effectually the unprinted ground, without touching the coloured pattern, and this no doubt is apparently the case, but the remarkable fugitiveness of the colours of modern printed callicoes is in all probability to be mainly attributed to the substitution of this more speedy method of colouring, to the old and more tedious, but safer mode.

HYPEROXYMURIAT OF MAGNESIA.

The manner of preparation, and the chemical and physical properties of this salt, are nearly the same with those of the preceding. It is composed of 60 Hyperoxymuriatic acid
25.7 Magnesia
14.3 Water

100.0

HYPEROXYMURIAT OF ALUMINE.

Pure and recently precipitated alumine, when treated in a Woulfe's apparatus, in the manner already mentioned, is dissolved; and upon pouring sulphuric acid into the liquor, a strong odour of hyperoxymuriatic acid is perceptible. This salt however cannot be obtained in a separate state.

It is made no use of.

P

PALLADIUM. See PLATINA.

PARTING

Is a term used by assayers, to express the separation of gold from silver. For an account of this process, see ASSAY, and GOLD, *Purification of*.

PASTEL. See WOAD.

PEARL. See SHELL.

PEARLASH. See CARBONAT OF POTASH.

PEARLSPAR. See BRAUNSPATH.

PEAT.

Peat, or turf as it is called by some, is a congeries of vegetable matter, in which the remains of organization are more or less visible, consisting of trunks of trees, chiefly oak, fir, birch, alder, hazle, and willow; of leaves and fruits, particularly hazle nuts; and of long stringy fibres, which appear to be for the most part the remains of the sphagnum palustre, and other aquatic mosses. It occurs for the most part in extensive beds called peat mosses, either occupying the surface of the soil, or covered to the depth of a few feet with sand, gravel, and other alluvial matters. It is met with abundantly in the Northern and in some of the central districts of Europe, in all moist uncultivated mountainous tracts, as high as vegetation extends; it is also frequent in low vallies and fenny plains; and in several parts of the Western shore of Great-Britain runs into the sea, to an unknown extent, as in the harbour of Oban in Argyleshire; in Lancashire, a little to the North of Liverpool; and near Towyn in Merionethshire. The depth of peat mosses is very various, from a few feet to twelve or fifteen yards, or even more. The consistence of peat is equally various, being sometimes in a semifluid state, forming a black impassable

* Chenevix.

wilderness, studded here and there by tufts of rushes: when more solid, it is scantily covered over with heath and coarse grasses, and is then passable by sheep and other larger animals, especially during the dry season of the year. In all deep peat mosses, it is found that the upper part of the peat is looser, of a lighter colour, and less inflammable than that which forms the lower part of the bed. When of a good quality it is moderately compact, and may readily be cut into solid masses, like bricks, with a sharp thin spade: if it manifests any considerable degree of elasticity and resistance to the spade, its quality is always found to be very inferior. By exposure to the air it dries slowly, being very retentive of moisture, acquires a brownish-black colour, becomes moderately hard, and in this state is very inflammable. By the further action of the weather it by degrees falls to pieces and is decomposed, though very slowly. When kindled in an open grate the best kind burns with a yellowish-blue flame almost like charcoal, and a less quantity of smoke than wood affords; it gives out a great quantity of heat, and is reduced to light ashes of a white or reddish yellow colour. Some varieties of peat are considerably changed with iron pyrites, on which account they effloresce and vitriolize when exposed to the air, and in burning give out a strong sulphureous odour, much smoke, and little heat, and afford a heavy reddish-brown ash. Sulphats of soda and magnesia are also occasionally found in peat, and produce a similar bad effect on it, considered as a combustible, as pyrites does.

By digestion in boiling water, peat affords a deep brown solution, slightly bitter to the taste, and containing an uncombined vegetable acid considerably resembling the suberic, with a portion of extract, and a little sulphat.

By dry distillation there comes over a watery ammoniacal liquor, an empyreumatic oil, and carburetted hydrogen, a considerable quantity of charcoal remaining in the retort.

Many ingenious attempts have been made, especially in France and Germany, to substitute with economy the charcoal of peat for that of wood, for culinary and metallurgical purposes, and it seems to be satisfactorily proved that a given bulk of the former burns somewhat longer, and affords a more considerable heat, than of the latter; but that it is incapable of withstanding the action of a forge bellows, and is apt to deteriorate the quality of iron that is smelted with it. Another objection however occurs to the employment of peat charcoal on the score of its being less economical, except in very particular circumstances, than wood charcoal. It cannot be prepared in the manner of common charcoal, on account of its loose texture, without a prodigious loss of substance and deterioration of quality; the manufacturer must therefore have recourse to distillation in iron cylinders or other vessels, but to effect this, so large a quantity of peat must be consumed as fuel, that the value of the charcoal, the oil, and ammonia, will hardly cover the expence. Hence it is that all the establishments in France for this purpose, though of considerable magnitude, and carried on with vigour and intelligence, have been entirely abandoned.

In this country peat is the common fuel of a large part of Wales and Scotland, and of many districts in England, where coal is not readily to be procured. It is employed not merely for domestic purposes, but for burning lime and bricks; and its ashes, though destitute of alkali, are in high estimation as a manure, being applied for the most part in the form of a top-dressing.

PECHBLENDE. See Uranium.

PECHSTEIN. See Pitchstone.

PELICAN, an article of chemical apparatus. See Appendix.

PERIDOT. See Chrysolite.

PERIDOT *granuliforme* (of Hauy). See Olivin.

PERLSTEIN. *Wern.* Pearlstone. *Jameson.* Its colours are pearl and smoke-grey, yellowish-grey, flesh-red, and reddish-brown, also greyish-black. It occurs in round and longish vesicles. Its lustre is shining and pearly. Its fracture is small, and imperfectly conchoidal. It is composed of thin concentric lamellar concretions. It is translucent on the edges, easily frangible and soft. It is composed according to Klaproth, of

75.25	Silex
12.	Alumine
1.6	Oxyd of iron
4.5	Potash
2.5	Lime
2.5	Water
98.35	

It occurs in porphyry, and often contains balls of obsidian. It is found near Tokay in Hungary.

PETROLEUM. See Bitumen.

PETROSILEX. See Hornstone.

PEWTER. An alloy of Tin, which see.

PHARMACOLITE.[a] Chaux arseniatée. *Hauy*.

The colour of this mineral is snow-white; it occurs in small crystals occasionally prismatic, but more commonly acicular; sometimes the crystals are aggregated into bundles, and sometimes into mamuilated masses. Internally it is glistening, with a silky lustre. Its fracture is radiated or divergingly fibrous; it also presents large and small granular distinct concretions. The crystallized varieties are transllucent. It is very tender, and easily frangible.

It is soluble in nitric acid without effervescence. By the action of the blow-pipe it disengages an arsenical odour, and leaves an involatilizable residue. By the experiments of M. Selb, it was first ascertained to be a compound of lime and arsenic acid, with a little cobalt; a result which has been fully confirmed by a compleat analysis of it by Klaproth.[b]

One hundred grains of this mineral, according to the celebrated chemist last mentioned, lose by being moderately heated, and without the disengagement of any arsenical or other odour, or visible vapour, 22.5 grains, which are water of crystallization. The residue by digestion in nitric acid is dissolved, except 6 grains, which are a mixture of silex and alumine. The nitrous solution affords with acetite of lead, a copious precipitate of arseniat of lead, which, when washed and dried, weighed 138 grains, and indicated 46.5 of arsenic acid. The remaining fluid, with the washings, was moderately evaporated, and treated with a little muriatic acid, to separate the small portion of acetited lead which it contained, and was then mixed with sulphuric acid: this produced a large deposit of sulphat of lime, which after being washed with dilute spirit of wine, and heated to redness, weighed 54 grains, and therefore contained 23 grains of lime. The residual liquor being neutralized by carbonated soda, and evaporated to dryness, was redissolved in water, and left behind 0.5 grs. of a blue powder, which tinged borax of a deep blue colour, and was oxyd of cobalt. Hence 100 parts of pharmacolite contain

tain	46.5	Arsenic acid
	23.	Lime
	0.5	Oxyd of cobalt
	6.	Silex with alumine
	22.5	Water
	98.5	

Of these the first three ingredients appear to be the only ones necessary to the constitution of this mineral.

It has been found near Wittchen, in Swabia, in a vein of granite, accompanied by heavy spar and gypsum. It has also been met with at St. Marieaux-mines in France.

PHLEGM. This term has long been used to signify the mere watery part which rises in many compound distillations. Thus the first product from oil of vitriol when heated, is an aciduious *Phlegm*.

PHLOGISTON. All that we think it necessary to say on this merely theoretical subject, will be found under the article *Oxygen*.

PHLOGISTICATED AIR. See Azot.

PHLOGISTICATED ALKALI. See Prussiat *of Potash*.

PHOSPHORUS. *(Kunckel's)*

Phosphorus is a simple substance, much resembling wax in consistence, when pure nearly of the transparency of gum copal, of a colour varying from amber red to the faintest straw, highly combustible, and when oxygenated producing a strong and peculiar acid.

It was discovered by a German chemist of the name of Brandt about 150 years ago, and the preparation was long kept a lucrative secret in the hands of a few persons, but as it was generally known to be prepared from human urine, and as the method then employed, though tedious and disgusting, was extremely simple, it was detected by several chemists, and the real nature of phosphorus has been gradually explained by a vast number of ingenious and elaborate researches.

The earliest mode of preparing phosphorus[a] was the following: a large quantity (amounting to several gallons) of human urine was collected, and after remaining for a time to become putrid it was evaporated to dryness in any suitable vessel. The residue consists of the animal extractive matter and of many salts, *(for which see the article Urine)* among which are two with phosphoric acid, the phosphats of soda and of ammonia. This residue was then mixed with charcoal in powder, and heated gradually to low redness in an iron pot, by which the animal matter was destroyed, till the mass began to send forth blue luminous vapours. It was then removed into a coated earthen retort with a receiver, and heat applied gradually till it reached the utmost intensity, during which the phosphorus distilled over and partly concreted in the neck of the retort, and partly fell in drops into the receiver. This, which was at first black and foul was purified by melting, and was formed into sticks, which were long sold at a very high price as a great

[a] Brochant II. p. 523. [b] Klap. Analyt. Ess. II. p. 220. [a] Macquer, Chem. Dict.

philosophical curiosity, for making luminous writing and other entertainment.

In this process the quantity of phosphorus yielded was excessively small compared to that of the urine employed, for of all the constituents of urine it is only the phosphat of ammonia that is concerned in the production of phosphorus, the heat driving off the ammonia, the phosphoric acid is left without a base, and it is then decomposed by the charcoal which abstracts its oxygen, and leaves the phosphorus uncombined and volatilizable by the heat. The phosphat of soda of the urine is not altered.

After a while Margraaf, an excellent chemist of Berlin[b] found that the product of phosphorus was much augmented by adding to the extract of urine some of the *plumbum corneum*, or submuriat of lead, left after distilling sal ammoniac and litharge, the reason of which is found to be that this salt decomposes (in part at least) the phosphat of soda of the urine, which hitherto had been useless, forming a phosphat of lead, which is equally decomposable by charcoal with the phosphat of ammonia.

This method has been still further improved of late years by Giobert of Turin, whose process for preparing phosphorus from urine we may mention here, though it is not the one generally employed. It is the following: into a quantity of urine pour a moderately dilute solution of acetite or nitrat of lead, which will immediately produce a copious greyish white precipitate of phosphat of lead, and add the metallic solution as long as it produces any considerable milkiness. Run the whole through a linen filter, and immediately mix the phosphat of lead that remains with a fourth of its weight of finely powdered charcoal, (the exact proportions of each being of no great consequence) and dry the black pasty mass in an iron pot heated barely red. Then transfer it to an earthen retort, and raise the heat to moderate redness. Much fetid ammoniacal oily vapour passes over at first, and till this disappears the heat is not to be raised higher than to a low red. Then change the empty receiver for one half full of water, or dip the elongated beak of the receiver about an inch under water, and encrease the heat to a full glowing red, and in about half an hour the phosphorus distills. The particular management of the process and subsequent refining of the phosphorus are the same as are employed in the more common process, and will be presently described. When all is finished, the retort will contain the lead reduced, and mixed with the undecomposed charcoal, but as some chemists assert, it is in the state of phosphuret of lead. The average quantity of phosphorus yielded is found to be about 14 to 18 parts from 100 of the phosphat of lead well washed and dried, but this is not necessary, as the other urinous matters that adhere to it are readily dispersed in the distillation. It does not appear to require so intense a heat to obtain phosphorus in this way as in that which will be next described. The salts of zinc added to urine produce also a precipitate which is the phosphat of zinc, and some phosphorus may be procured from it by distillation, but much less than from the phosphat of lead: as the zinc rises in distillation along with the phosphorus, and phosphuret of zinc concretes in the neck of the retort.

Whilst phosphorus was prepared in the old way by evaporating urine, it was a very disgusting, tedious, and somewhat difficult process, but it was soon discovered (by Gahn, as is commonly said, but as appears from some authority, more probably by Scheele) that the phosphoric acid was contained in abundance in the white earth left after the calcination of Bones, united with lime, and when separated by chemical means phosphorus could be prepared from it with much more ease and certainty. This method is now almost universally preferred, as it requires but little apparatus, and is in no way offensive nor difficult. The earth of bones consists of phosphat of lime, (mixed with a little carbonat) and as the sulphuric acid has a stronger affinity for lime than the phosphoric, it is this which is employed for procuring the phosphoric. This process of making phosphorus consists of two distinct operations, viz. the separation of the phosphoric acid from the bone-ash, and the distillation of the acid and charcoal to obtain the phosphorus: it is performed in the following manner, with some slight variations. Take any quantity (suppose 4 lbs.) of powdered bone-ash, or calcined earth of bones, such as cupels are made of, put it into an earthen pan capable of holding 4 gallons, mix it at first with about 4 quarts of water, and then add gradually with incessant stirring, 2 lbs. of strong sulphuric acid. A very great heat is excited by the mixture, and some effervescence, (which last arises from the carbonat of lime,) and it should be prevented from clotting by rapid stirring. Then add about a gallon of water and allow it to remain for a day with occasional stirring.

[b] An. Chim. Tom xii.

The mixture thickens extremely by ſtanding, ſo that if this quantity of water is not ſufficient, more muſt be added to bring it down to the conſiſtence of thick ſoup. Then pour the whole mixture on a linen bag, by which the clear liquor will run through, and leave the white pulpy maſs on the filter, which muſt be ſtrongly preſſed and then waſhed with a pint or two of boiling water to extract all the acid. Unite all the liquors together, and after they have ſtood a little to become quite clear they are fit for evaporation. This liquor now contains almoſt all the phoſphoric acid of the bone-aſh, chemically united with a portion of undecompoſed phoſphat of lime, and alſo holding ſome ſulphat of lime in ſolution. The white maſs in the filter is ſulphat of lime, which may be thrown away. The liquor may be either boiled down immediately, or as Dr. Higgins recommends, firſt ſaturated with ammonia and then evaporated. The former is the commoneſt method, and where the object is only to procure phoſphorus and not pure phoſphoric acid, it is probably preferable. The boiling down of this large quantity of acid liquor is tedious. It may be done either in large Wedgewood-ware evaporating pans over charcoal, or in a copper pan, as this acid does not readily act on copper. Keep up a briſk heat and continue the boiling almoſt to dryneſs, during which the clear liquor as it becomes concentrated will be muddy from the ſeparation of ſelenite, and a greaſy looking paſty acid maſs will depoſit on the ſides of the veſſel. When the liquor is boiled down nearly to dryneſs, carefully add to it the ſcrapings from the ſides of the veſſel and let it ſtand ſome hours that all the ſelenite may be precipitated. Then rediſſolve the whole in as little cold water as will take up all the acid, filter it off from the ſelenite, and evaporate it till it becomes a paſty puffy maſs, which is now intenſely ſour and conſiſts of phoſphoric acid holding ſome phoſphat of lime. Then mix it thoroughly with a fourth of its weight of powdered charcoal, and dry the whole in any veſſel with a heat juſt below redneſs. It is then fit for the ſubſequent proceſs of diſtillation.

Dr. Higgins recommends the following management of the liquor ſeparated from the ſelenitic maſs by filtration:[c] ſaturate it with carbonat of ammonia, and boil, which will cauſe the ſeparation of all the remaining earth; then evaporate the clear liquor in a leaden boiler till it is reduced ſo far that cryſtals of phoſphat of ammonia will depoſit by cooling. Pour this ſolution while hot, into a thin glaſs balloon, cover the mouth looſely with an inverted pot, and heat the balloon ſlowly till the bottom is obſcurely red. A copious ſublimate ariſes, conſiſting of ſulphat of ammonia, with moſt of the ammonia by which the phoſphoric acid was neutralized, and the latter acid (not being volatilizable by any heat) remains in the form of a colourleſs tranſparent glaſs, eaſily ſeparable from the veſſel by the blow of a hammer. It is phoſphoric acid in great purity, containing probably nothing but a little remaining ammonia. This is then powdered in a mortar and thoroughly mixed with about half its weight of charcoal, and is then fit for diſtillation.

The proceſs of diſtilling phoſphoric acid and charcoal to obtain phoſphorus is in itſelf very ſimple, but ſome precautions are required in the management. Phoſphoric acid by itſelf vitrifies in a red heat and is not further changed by any intenſity of fire, but when in contact with any carbonaceous matter it is decompoſed, yielding its oxygen to the charcoal, whilſt the phoſphorus flies off in the form of vapour, which is condenſed when it arrives at a cooler place and concretes into a brown-red waxy matter. A very ſtrong red or red-white heat is required for this purpoſe, (probably about the degree ſufficient to melt copper) ſo that the retort muſt be of earthen-ware and fitted to a powerful reverberatory furnace, or ſurrounded with burning charcoal in conſiderable maſs and heaped up for ſome height above its neck. As at this temperature the common crucible ware becomes very porous, much of the vapour of the phoſphorus would ooze through (even without any accidental flaws or cracks) ſo that the retort ſhould previouſly be coated with a vitreſcent lute, of which there is none better than ſlacked lime brought to a moderately thin conſiſtence by a ſaturated ſolution of borax in water, and bruſhed over the outſide of the retort and ſlowly dried. This when heated forms a thin glazing which ſtops up moſt of the pores of the veſſel. In the diſtillation the contact of the external air muſt be carefully excluded, otherwiſe the phoſphorus as ſoon as formed would take fire and conſume ſpeedily. This is prevented ſimply by elongating the neck of the retort with another earthen or metal tube cemented to it by *glue lute,* (*ſee the article Cement*) and dipping the end of the ſecond tube about an inch in a pan of water. Thus all the gaſſeous products paſs through the water, and

[c] Higgin's Minutes. p. 252.

the phoſphorus partly concretes within the tube and partly falls to the bottom of the water.

The proportion of one part of charcoal to two (by weight) of the concrete acid, is much more than is neceſſary to decompoſe the acid, but it is uſeful to have an exceſs of charcoal to protect the retort from being corroded by the acid, which operates as a powerful flux for all earthy mixtures.

The retort being filled with the mixture of charcoal and acid, (which may be done nearly to the neck in caſe the acid be thoroughly dried previouſly in a low red heat) put it into the furnace and raiſe the heat very gradually to a moderate redneſs. At firſt with the air of the veſſels a quantity of mixed gaſſes, chiefly carbonic acid and hydrocarbonate, paſs over, and when theſe have nearly ceaſed, increaſe the heat to a full glowing white-red and keep it up to this degree during the remainder of the diſtillation. The firſt indication of the production of phoſphorus is that the gas as it paſſes out of the water becomes white and luminous in the duſk, which is followed by a gas ſtill more inflammable, each bubble of which takes fire in the air and burns with a brilliant flame and ſlight ſnapping noiſe as ſoon as it riſes above the ſurface of the water beneath which the end of the tube is dipped. After this the phoſphorus riſes in ſubſtance, and if the quantity of materials in the retort be large, ſome of it falls down in drops into the pan of water, where it immediately congeals, but by far the greater part concretes in that part of the neck of the retort which reaches out of the furnace, and in the tube by which it is elongated. Sometimes the paſſage is entirely blocked up by the congealed phoſphorus which might endanger the burſting of the retort, to aſcertain which a flexible wire may be thruſt up now and then (but without raiſing the end of the tube out of the water) and if the paſſage is not free, lay a red hot iron bar on the outſide of the tube where the paſſage of the wire is obſtructed, which will melt down the phoſphorus.

It is not eaſy to aſcertain when all the phoſphoric acid is decompoſed, and all the phoſphorus has paſſed over, for the efflux of gas nearly ceaſes before the diſtillation is compleated, ſo that experience muſt guide the operator when to ſtop. If the retort continues ſound, no loſs of phoſphorus is incurred by continuing the fire longer than neceſſary, ſo that it is better to exceed than to fall ſhort of the requiſite time. But as earthen veſſels will ſooner or later vitrify and ſink down in a very ſtrong heat, the fire ſhould be kept below the degree at which earthen fire-veſſels ſoften, and the retort ſhould be now and then examined. Sometimes the retort unfortunately cracks in the middle of the diſtillation, which may be diſcovered by a bright green flame and a denſe white ſmoke around the part that has given way. This may ſometimes be cloſed by immediately preſſing on the part ſome linſeed oil fire lute, (*as deſcribed in the article Cement*) but if this fails the retort muſt be taken out, and as much of the materials as poſſible ſaved for a future operation.

When the diſtillation is judged to be finiſhed, remove the tube from the water and inſtantly cork it tightly to prevent the acceſs of air, which would inflame the phoſphorus, and let the retort cool. When quite cold break it with a hammer juſt where the neck joins with the body of the veſſel, holding it in the ſame poſition as it ſtood in the furnace, to prevent the charcoal within the retort from mixing with the phoſphorus ſublimed in the neck and tube, and throw the latter into cold water. The phoſphorus may then be got out by removing the tube into boiling water, which melts out the phoſphorus, but in this as in all operations on this inflammable material whenever a ſufficient heat to melt it is applied, (which is about 100°) every thing ſhould be done under water, as it kindles a little above its melting temperature, and burns vehemently the moment it becomes expoſed to the air.

The phoſphorus produced in this proceſs is very brown and foul, and is mixed with a good deal of a brown red powder which diffuſes itſelf in water like clay, and conſiſts chiefly of phoſphorus ſo far oxygenated as to be no longer combuſtible.

The quantity of product varies extremely, but is the moſt when the materials are dry and the diſtillation ſlow. Pelletier obtained 60 oz. of phoſphorus by a ſingle proceſs from the acid of 36 lbs. (576 oz.) of bone-aſh decompoſed by 30 lbs. of ſulphuric acid.

The brown red phoſphorus may be purified by ſeveral methods. The ſimpleſt is the following: take a piece of thin white leather, put the impure phoſphorus in the middle and tie up the ends very tight ſo as to encloſe it in a leather bag; then plunge it into boiling water and ſqueeze the bag with the fingers, by which the melted phoſphorus will ooze through in drops, that coaleſce at the bottom of the water into a clear pure waxy phoſphorus almoſt tranſ-

parent and colourless. All this should be done under water. What remains in the bag is a mixture of black carbonaceous matter, with a good deal of the red incombustible oxyd of phosphorus already mentioned. Care must be taken in doing this not to get any of the phosphorus beneath the finger nail, which might occasion a dangerous and painful burn. The leather will not serve a second time.

Another way is by distillation. Phosphorus is perfectly volatile at a heat of about 200° and it rises in the second distillation quite pure and transparent. In doing this, all access of air should be prevented, as the heat required to sublime it much exceeds that at which it takes fire in the air. The air within the vessel is speedily deoxygenated by the action of the phosphorus at a common temperature, and of course no combustion can take place when the phosphorus is further heated in this same air. Or, the phosphorus may first be melted to the bottom of the retort by hot water, and the latter displaced by azot or hydrogen, (in which phosphorus is equally uninflammable) and then a heat applied sufficient first to melt and then to sublime the phosphorus.

Another mode of purifying it is to melt it in nitro-muriatic acid, and to shake it thoroughly in the acid, whereby on standing again it concretes into a very white transparent mass. The red oxyd of phosphorus is separated in this process and is converted into phosphoric acid. This method however does not appear to be so good as the first mentioned.

Phosphorus when newly purified is nearly transparent and of a waxy consistence, but when kept in water it soon becomes covered with a reddish-white opake crust. It is insoluble in water. Its specific gravity is 1.77.

The most remarkable phenomena relating to phosphorus are those that occur during its combustion. When a stick of phosphorus is simply exposed to the air, if the temperature be above 45°, it constantly sends off a white vapour of a very strong unpleasant smell, somewhat like that of garlic, which is more copious and dense in proportion to the temperature. This vapour in the dark is seen to be a blue lambent flame, and it continues to be emitted from the phosphorus for a great length of time with little apparent alteration, and without giving out any sensible heat. Hence it is that if characters are traced by rubbing a stick of phosphorus on a board, or any rough surface, they are made luminous by the minute quantity of phosphorus abraded, when exposed to the air. This however is a real though slow combustion, and in time the whole of the phosphorus is partly wafted away in luminous vapour, and partly converted into acid on the spot, and the light ceases. When a piece of phosphorus is put into a silver spoon and held near a fire or candle, the white vapour becomes extremely dense and copious, the phosphorus melts at about 99°, and at 148° it takes fire and burns with a very bright greenish white flame and heavy white smoke. No residue is left in the spoon, but if the smoke is received into any vessel it condenses on cooling into a very sour liquid, which is the phosphoric acid. Thus then it appears that there are two modes of combustion of phosphorus, one a slow combustion, with scarcely any sensible heat, and in which much of the phosphorus is slowly volatilized by the surrounding air; and the other a rapid combustion with vivid light and intense heat. The former begins at the temperature of from 40° to 45° (in the atmosphere) and whilst the phosphorus remains solid; the latter occurs at the heat of about 148° and after fusion. The former is not dangerous to the touch, but the latter produces a very rapid destruction of the skin and flesh, so that phosphorus should always be handled with great caution, as very serious burns have arisen from carelessness in this respect.

Phosphorus when very pure dissolves in alcohol though very sparingly. As it dissolves, the liquor takes the peculiar unpleasant smell of phosphorus.[e] This solution is not of itself luminous, but if a drop of it is let to fall on a little water at the bottom of a glass vessel in perfect darkness, the moment it touches the water a faint blue lambent flame is seen to undulate on the surface and gradually to fill the vessel. If the air of the vessel is changed by blowing into it, the same phenomenon is renewed repeatedly till all the phosphorus is extracted from the mixture. In like manner if a wetted feather be dipped in the phosphorized alcohol, the air above the point of contact immediately becomes luminous. In these experiments, there appears a kind of double decomposition, the phosphorus uniting with the atmosphere, and the alcohol with the water, and the heat excited by the mixture of these two liquors doubtless favours the decomposition.

Oil of turpentine and the other essential oils dissolve phosphorus with more facility and in greater quantity than alcohol. If a little of

[e] An. Chim. tom. 24.

this solution is smeared over the face or hands, the warmth of the body causes the oil to evaporate speedily, after which the thin insensible pellicle of phosphorus that remains becomes strongly and uniformly luminous, and continues so for some time. This amusing experiment is no ways hazardous, as the quantity of phosphorus left on the skin is too small to do mischief.

Phosphorus may be equally well dissolved in the fixed oils. Oil of olives or almonds are the most convenient. Heat the oil in any vessel with the phosphorus for about a quarter of an hour, and the oil will dissolve enough of the phosphorus to be extremely luminous when smeared over the skin or any warm surface.

Sulphuric ether dissolves phosphorus, but this solution is not of itself luminous. Alcohol added to it makes it milky.

The habitudes of phosphorus with the different gasses offer several very interesting phenomena. These have been examined with great care by Fourcroy, Vauquelin,[f] Spallanzani,[g] Brugnatelli,[h] and others, with the particular view of refuting some observations of Goettling on the luminousness of phosphorus in azotic gas, which were supposed to militate against the modern theory of combustion.

When a stick of pure phosphorus is introduced into very pure oxygen gas, no light whatever is perceived, though the experiment be made in perfect darkness, at any temperature below 80° or 81°. But if it be raised to this point by putting the warm hands on the outside of the jar, the phosphorus becomes very luminous, and is surrounded with white vapours. This appearance continues till the temperature is reduced to 55°, when it ceases entirely. This luminousness is caused by a low combustion of the phosphorus and consequent generation of phosphoreous acid, so that in this, as in all the subsequent experiments, whenever the luminous appearance has taken place litmus paper within the jar will be reddened. From 81° to 104° this slow combustion continues but with increasing rapidity, but at about 104° the phosphorus, which is then melted, takes fire and burns rapidly with intense heat and flame as already described. But though phosphorus does not begin to be luminous, and therefore to undergo combustion in pure oxygen at a lower temperature than 81°, it imperceptibly dissolves therein at the heat of 55°, and perhaps lower, as will be presently shewn.

Phosphorus introduced into perfectly pure azotic gas, (such as that extracted from muscular flesh by weak nitric acid) is not luminous at any temperature, but may be melted and even sublimed therein without shewing the least light, or undergoing the smallest combustion. It dissolves in it however at 55° and enlarges its bulk about $\frac{1}{40}$ according to Berthollet, as has been mentioned under the article EUDIOMETRY, (*which see*). But if a single bubble of oxygen gas, pure or impure, be thrown up into a jar of this phosphorized azot, a pretty strong blue light is perceived at the moment of contact which continues for a short time. The same effect, but in a much greater degree, is produced by inverting the experiment, and adding bubbles of phosphorized azot to oxygen gas, in which case the whole vessel is filled with a fine lambent blue flame. Not only pure oxygen, but common air or any other mixture of oxygen will render phosphorized azot strongly luminous. It has been mentioned that phosphorized oxygen gas does not of itself become luminous till heated to 81°, but (what appears at first very remarkable) if a jar be filled with it and kept at the temperature of 55° and a few bubbles of azot be thrown up, the whole jar immediately shines with a bright blue light like that of the electric aura. It appears therefore that when phosphorus, azot, and oxygen are present, the phosphorus first combines with the azot, and being thus extremely divided, it is able to undergo combustion with oxygen at a much lower temperature than where the azot is absent. This is exactly what takes place when phosphorus is confined at a moderate temperature in atmospherical air, and hence to employ phosphorus as an eudiometer at this heat the presence of the azot is necessary to set in action the combustion.

Messrs. Fourcroy and Vauquelin found that when phosphorized oxygen had been first made luminous by raising the heat to 81°, and *then* cooled to 55° and mixed with azot, no light could be perceived.

The same chemists also observe that when phosphorized oxygen and phosphorized azot (both made by keeping phosphorus in the respective gasses at a low temperature for some hours) are mixed together at 55°, no light is perceived, which is a very singular fact, and appears to contradict the experiment in which azot renders phosphorized oxygen luminous, or oxygen, phosphorized azot, at the same tem-

[f] An. Chim. tom. 21. [g] Do. tom. 22. [h] Do. tom 24.

perature. The only difference in this caſe is that *both* gaſſes are previouſly ſaturated with phoſphorus, inſtead of only one.

When a ſtick of phoſphorus is confined in hydrogen gas no light is produced, but after a time the gas diſſolves ſome of the phoſphorus, and then, like phoſphorized azot, it becomes luminous on the contact of oxygen or any air containing oxygen. In like manner pure hydrogen added to phoſphorized oxygen renders it luminous, and even at as low a temperature as 44° according to Spallanzani.

With hydrogen, phoſphorus unites in two ſtates of ſaturation, the loweſt is that which has been juſt mentioned, and is produced by keeping phoſphorus in hydrogen at a moderate temperature. The other is the gas produced by boiling the phoſphorus in an alkaline ſolution, and will be afterwards deſcribed. The former gas is merely luminous by expoſure to air or oxygen, the latter takes fire and burns with a bright flaſh and ſlight exploſion; the former therefore may for the preſent be diſtinguiſhed by the term *ſub-phoſphuretted hydrogen*, and the latter *phoſphuretted hydrogen*.

Phoſphorus kept in ſulphuretted hydrogen diſſolves therein, but is not luminous. On adding common air a large blueiſh flame is produced. This luminous gas ſeems to be more permanent and condenſed than the others, attaching itſelf to the hands or to the veſſel in which the experiment is made, and giving them a very bright luminous coating, which remains for ſeveral minutes.

No very intereſting appearance takes place when phoſphorus is confined in the other gaſſes, but when thrown into the oxymuriatic acid gas it ſoon takes fire, and burns rapidly and beautifully.

In all the above experiments where it is aſſerted that the gas containing the phoſphorus remains abſolutely dark, it is underſtood that it is confined by mercury, for when kept over water, the oxygen which this fluid uſually contains may be diſengaged, and the minuteſt quantity will become ſenſible by ſuch a delicate teſt.

The ſolution of phoſphorus in oxygen gas at a low temperature is a very curious circumſtance, for it muſt imply a very intimate union of the two without any approach to combuſtion, ſince at any time combuſtion may be excited in the mixture either by raiſing the heat to 81°, or by adding azotic or hydrogen gas, and ſince after the temperature has been raiſed to the point of luminouſneſs and ſlow combuſtion, and again reduced, no effect is then produced by the above additions.

The ſub-phoſphuretted hydrogen having been already mentioned, we may proceed to deſcribe the phoſphuretted hydrogen. This gas was firſt diſcovered by Gengembre, who prepared it by boiling phoſphorus in alkali. It is eaſily produced in the following way: put ſome pieces of phoſphorus in a very ſmall bottle with a curved tube, or in a ſmall retort, fill the veſſel to the neck with a weak ſolution of cauſtic potaſh, and heat it to boiling, taking care to dip the open end of the bottle or the tube in water or mercury to prevent the acceſs of air. When the ſolution begins to boil, bubbles of gas riſe to the ſurface, which kindle immediately and burn with a bright flaſh within the veſſel as long as any oxygen remains. This cauſes a rapid abſorption, ſo that unleſs the veſſel is nearly full, much of the water or mercury ruſhes up, but after a while this ceaſes, and the diſcharge of gas is copious and regular. It is the peculiar property of this phoſphuretted hydrogen to burn with a very vivid flaſh and a ſlight ſnapping noiſe the moment it comes in contact with the atmoſphere, and after each bubble has thus exploded, a very remarkable circular ring of white ſmoke riſes from the flaſh, and mounts about two or three feet in the air, gradually widening till it diſperſes. This gas if received by bubbles in a jar of oxygen gas burns with a ſtronger exploſion and a brilliant flaſh of flame, perhaps more beautiful than any other that chemiſtry can exhibit. Phoſphuretted hydrogen may alſo be produced by heating phoſphorus very ſtrongly, and ſubliming it in an atmoſphere of hydrogen. Another method of producing it is ſimply by dropping into water ſome phoſphuret of lime, as will be preſently mentioned.

Phoſphuretted hydrogen has a ſtrong and unpleaſant ſmell ſomewhat like that of ſtale fiſh. It is conſiderably lighter than common air, but its compoſition ſeems to vary according to the circumſtances and time of its formation. If kept in the dark, and over mercury, it retains its inflammability for a length of time, but in the light it is ſoon changed, and no longer kindles on admiſſion of common air.

When this gas recently prepared is agitated with cold water, a conſiderable quantity is abſorbed, and a liquor is formed of a faint yellow colour, a diſagreeable ſmell and a bitter and nauſeous taſte.[1] It is not luminous in the

[1] Raymond in Ann. Chim. tom. 35.

dark. Water thoroughly purged of air by recent and long continued boiling, will absorb at 55° about a fourth of its bulk of the gas.

When this solution is heated, the gas is again expelled, at a heat below boiling, unaltered, and as inflammable as before.

If the solution is exposed to the air it soon becomes turbid, and deposits a considerable quantity of red oxyd of phosphorus, whilst hydrogen escapes, which is now no longer spontaneously inflammable. In time the liquor becomes simply water containing a little oxyd of phosphorus.

This solution of phosphuretted hydrogen when made with well boiled water does not change the colour of litmus, and therefore is neither acid nor alkaline. It speedily alters many metallic solutions, reducing the metal to the state of a phosphuret. This is particularly remarkable when added to the solutions of silver, mercury, and lead, which it immediately blackens and separates a phosphuret of the metal, which in time is changed to a phosphat.

Phosphorus scarcely if at all unites with any of the three alkalies at any temperature.

With lime phosphorus unites by a moderate heat and forms a compound which has some curious properties. It may be made in the following manner.[k] Put into a long dry thin phial about half a dram of well burnt powdered lime, then about half this quantity of phosphorus, and fill it with alternate strata of lime and phosphorus. Stop it loosely with a cork, and bury it to the neck in hot sand, and keep the heat to a degree just below redness till the lime is uniformly impregnated with the phosphorus, and is of an auburn colour. In this process the phosphorus rises in vapour through the lime, and a part unites with it into a phosphuret, but some escapes by the cork and burns off. When the process is finished, for which no exact rule can be given, press the cork in to prevent the air from entering in cooling, and to keep it for any length of time the bottle should be inverted over mercury.

The phosphuret if duly prepared is friable and readily broken down in the bottle when cold by an iron wire, and at this point the process should stop. If continued longer, too much of the phosphorus is expelled, and the phosphuret will not present the usual appearances; if too little, the mass is hard.

When a quantity of this phosphuret is thrown into water about blood warm, it swells and crackles, and bubbles mount up, which take fire as soon as they reach the air, and burn with a bright flash and snapping noise on the surface of the water. This gas is phosphuretted hydrogen, the properties of which have been already described.

By a similar process phosphorus may be made to combine with barytes, and when melted, it exhibits the same phenomena.

Phosphorus appears to unite with charcoal during the process of the distillation of phosphorus by charcoal and phosphoric acid. This compound (according to Proust[l]) is the substance that remains in the leather bag when the impure phosphorus has been strained through it as already mentioned, but it is besides mixed with some uncombined phosphorus. It is red, and does not melt like pure phosphorus. Distilled *per se* in a close vessel the excess of phosphorus sublimes at a moderate heat, and there remains an orange red light flocculent mass, apparently homogenous, which this excellent chemist considers as the true phosphuretted charcoal. If the heat is raised to redness most of the *combined* phosphorus is sublimed, and the residue is little else than charcoal.

If a little of the phosphuretted charcoal is laid on a red hot iron plate, the phosphorus burns first, and forming phosphoric acid it melts with and involves the remaining charcoal and preserves it from the further action of the fire. Caustic potash in solution boiled with this compound produces no effect upon it, which shews how intimate is the chemical union of the constituent parts. It is probably this substance that forms the red or black powder which so often appears in many operations with common phosphorus.

Sulphur and phosphorus unite in several proportions, forming a very interesting compound, which is one of the most inflammable and dangerous combustibles that we are acquainted with. Phosphuretted sulphur was first noticed by Margraaf, afterwards by Pelletier,[m] who has shewn the mode of combining them, and the great fusibility of the compound, and more lately Mr. Accum[n] and Dr. Briggs[o] have given very interesting papers on this subject. From all these sources the following particulars may be collected. This substance may be made by heating the phosphorus and sulphur in the required proportions in water till the phosphorus melts, which soon dissolves the sulphur and forms a yellowish mass, which is the

[k] Higgins.
[l] An. Chim. tom. xxxv. p. 45.
[m] Memoirs, &c. de Pelletier. tom. 1.
[n] Phil. Journ. 8vo. vol. 6.
[o] Do. vol. 7.

compound in question. Phosphorized sulphur melts at a much lower temperature than phosphorus itself, so that a heat much less than that of boiling water will be sufficient, and on account of the extreme risk of explosion when the heat is too great, no more than is absolutely necessary should be used. The fusibility of the compound increases with the proportion of sulphur. Thus Pelletier found that phosphorus alone, liquified by heat and allowed to cool, solidified at a temperature of from 90° to 100°. But all the mixtures of phosphorus and sulphur remained fluid at a much lower temperature. The particular experiments are as follows:

Phosphorus		Sulphur		
72	with	9	congeal at	77° Therm.
72	- -	18	- - -	59
72	- -	36	- - -	50
72	- -	72	- - -	41
72	- -	144	- - -	55

but when the quantity of sulphur exceeds that of the phosphorus the combination appears less perfect.

If equal parts of the two ingredients be melted under water at a heat not exceeding 180°, only a certain portion of the sulphur unites with the phosphorus, and the remainder may be washed away with cold water. This compound is yellow and friable, melts by the heat of the hand, and takes fire at about 112°. Two parts of phosphorus and one of sulphur are very convenient proportions for making this compound. They are to be put into a flask with water, and melted in a heat considerably short of boiling, and kept for a short time till the union is compleat. The vessel should on no account be shaken whilst the materials are fluid, for Mr. Accum relates a most dangerous explosion which took place in consequence. Neither should the water be allowed to boil in which the phosphorized sulphur is contained, for after a short time the mixture has been known to explode with prodigious violence, and with a large volume of flame. Yet, on the other hand, Mr. Accum, in another instance, kept a quantity of this mixture under a pretty long column of boiling water for a considerable time without accident; so that till we are better acquainted with the precise circumstances that produce explosion of this dangerous compound, such an event should always be expected and guarded against, when the mixture is heated in water, to within a few degrees of the boiling point. This substance also should be handled with still more caution than phosphorus, for it takes fire with a moderate heat, and even in the temperature of the air when slight friction is used.

Phosphorus and sulphur may also be safely combined in a close vessel without water. For this purpose, take a glass tube hermetically sealed at one end, put into it the phosphorus and sulphur, both perfectly dry, cork it very tight, and plunge the tube into hot water, which is to be gradually brought to boiling. The sulphur and phosphorus will unite without explosion, and when removed from the water, but still fluid, the tube may be shaken to compleat the union, care being taken to keep it well corked all the time.

Phosphuretted sulphur has the property of decomposing water without the assistance of alkalies or any other substance, a property not possessed by phosphorus or sulphur singly. The gas thus generated is a mixture of phosphorus, sulphur, and hydrogen, has the peculiar smell of both sulphuretted and phosphuretted hydrogen, and is luminous in the air, and if recently prepared, takes fire spontaneously, and burns with a greenish flame and a white ring of smoke. This compound gas was procured by Mr. Accum, (though not without risk of explosion) by putting two drams of phosphorus with two of sulphur into a Wedgwood-ware tube, closed at one end, and furnished at the other with a perforated cork, and bent glass tube fitting it, which was dipped under a jar of water. Four ounces of water were added to the mixture, and gradually brought to boil, during which nearly two quarts of the gas were procured, and without explosion. This gas was soluble in about four times its bulk of water by agitation. On throwing up common air to the gas, an instantaneous inflammation ensued, the vessel became filled with white fumes, and was soon lined with a white crust, which attracted moisture rapidly, and consisted of sulphur, sulphuric, and phosphoric acid. A considerable detonation is produced when this gas is mixed with the oxymuriatic acid gas.

The decomposition of phosphuretted sulphur by water, takes place, though slowly, at a heat scarcely higher than that of the atmosphere.

This compound (composed of three parts of phosphorus and one of sulphur) rapidly absorbs oxygen from the air, so that it may be employed with advantage as an eudiometer.

It is very rapidly oxygenated by nitric acid, even without heat, and converted into sulphuric and phosphoric acids.

Phosphorized sulphur is soluble in the fixed oils. If a little of it be rubbed in a mortar with

five or six parts of olive oil, and then put into a phial and allowed to stand for some little time, *without applying heat*, a liquid phosphorus is produced, which, when quite clear (so that none of the phosphuret is suspended in the oil) may be rubbed on the skin with perfect safety, and shines with much more brilliance than the solution of simple phosphorus in oil. Equal parts of this phosphuret in olive oil and oil of turpentine when shaken together and poured out of a vessel, gives in the dark the appearance of a beautiful shower of fire.[p]

The essential oils also dissolve this phosphuret and produce luminous solutions.

Phosphorus unites with most of the metals, forming compounds, which are all brittle, and mostly of a greyish-white colour. These phosphurets may be made either by heating the metal (in shreds or powder) with a mixture of phosphoric acid and charcoal; or by projecting phosphorus on the metal when red-hot. The phosphorus burns off from most of the metallic phosphurets by heating in the open air. They are individually described under the respective metals.

PHOSPHORIC AND PHOSPHOREOUS ACID.

The product of the combustion of phosphorus (or oxygenation in any other way) is an acid, which, though composed merely of phosphorus and oxygen, differs in a notable degree according as the oxydation is more or less compleat When incompleat, the *phosphoreous* acid is produced; when compleat, the *phosphoric* acid, so that of these two substances, the former contains more phosphorus or less oxygen than the latter. Some chemists have rather supposed that the phosphoreous acid is the phosphoric, holding some uncombined phosphorus in solution (in the same way as the *nitrous* acid may be considered as the *nitric*, holding dissolved nitrous gas) that is to say, that all the oxygen of the phosphoreous acid, is combined with a part only of the phosphorus, and in the proportions in which phosphoric acid is constituted, and that the superabundant phosphorus of the phosphoreous acid is only in loose combination with the remainder. Perhaps this is the proper way of considering this subject, for though the phosphoreous acid cannot be made by digesting phosphorus in the phosphoric acid, the former acid may be converted into the latter by mere heat, which drives off the excess of phosphorus.

The Phosphoreous Acid is produced by the *slow* combustion of phosphorus in atmospherical air, or that which is excited at all the common temperatures at which phosphorus becomes simply luminous without bursting into flame. It may be safely performed in small quantities at any heat below the melting point of phosphorus. The phenomena attending the slow and the rapid combustion of this substance in common air and in oxygen, have been already fully described.

Phosphoreous acid is conveniently prepared according to Pelletier's method. Inclose sticks of phosphorus, each in a small glass tube, quite open at one end, and drawn out to a capillary tube at the other. Arrange any number of these in a glass funnel, with the smaller ends of the tube downwards, and set the funnel in an empty glass bottle. The contact of the air immediately begins the slow combustion of the phosphorus, and a luminous vapour arises from each tube. But if this vapour (which is phosphorized azot in the act of union with oxygen) is allowed to disperse freely in the air, most of the phosphorus would be wafted away and lost; so that it is found necessary to confine it, by setting the bottle and funnel on a plate with a little warm water at bottom, and inverting over the whole a large bell-glass, with an opening in the middle, loosely corked, through which sufficient air may be let in from time to time, to maintain the slow combustion of the phosphorus within. In this way the phosphorus gradually deliquesces into a liquid acid, which falls in drops through the tube and funnel into the vessel below. About three times the weight of the phosphorus employed may be collected. The use of confining each stick of phosphorus in a separate tube is, to guard against the dangerous accident of the whole phosphorus taking fire; for though a single stick of it may be exposed to any natural temperature without kindling, it has been found that when a number of sticks are heaped together and exposed to the air from 65° to 70°, so much heat is generated by the slow combustion, as to cause the whole to inflame, which might be productive of the most serious consequences.

The acid which drops from the phosphorus in this process is the *phosphoreous*, and is a transparent liquor of the consistence of syrup, streaky when shaken, without smell, and with a strongly acid and peculiar taste.[a] When heated in a retort, it first thickens by the loss of its superfluous water, after which a number of bubbles arise to the surface, and break with a white smoke, which is luminous in the dark, smells

[p] Accum.

[a] Fourcroy.

ſtrongly of phoſphuretted hydrogen, and ſometimes actually takes fire. In an open veſſel theſe bubbles kindle the inſtant they reach the ſurface. By continuing the heat for a conſiderable time, all the ſuperfluous phoſphorus is burnt off, and the liquor is now converted into *phoſphoric* acid.

The phoſphoreous acid, though not ſaturated with oxygen, does not abſorb it, either when expoſed to the air or to oxygen gas, at leaſt not till after a conſiderable length of time, which, together with the great difficulty of expelling the exceſs of baſis by heat, ſhews the very ſtrong affinity between phoſphorus and phoſphoric acid, and ſeem to confirm the opinion already ſtated, with regard to the conſtitution of the phoſphoreous acid. By boiling with nitric acid however, the exceſs of phoſphorus is compleatly oxygenated, and the whole becomes phoſphoric acid.

Phoſphoreous acid added to thoſe of the metals that diſengage hydrogen during ſolution, ſuch as iron and zinc, diſſolves them with the production of a fetid gas, luminous in the dark, but not inflammable *per ſe*, which is hydrogen, holding a very ſmall portion of phoſphorus in ſolution, or what may be termed ſub-phoſphuretted hydrogen. The reſidue is the phoſphat of the metal employed.

This acid mixes with water in all proportions, and cannot be rendered ſolid by evaporation without loſing the exceſs of phoſphorus, which diſtinguiſhes it from the phoſphoric.

The combinations of this acid with the ſeveral baſes, form the *phoſphites*, which will be preſently deſcribed.

Phosphoric Acid.

This acid is found native in ſeveral ſtates of combination, particularly with lead and with lime, and it compoſes a great part of the earth of bones (whence it may be extracted in the way already mentioned), but it is never found native uncombined with any baſe. There are two methods of preparing it, one directly from phoſphorus, the other by the decompoſition of phoſphat of lime. The former gives it more certainly in a ſtate of abſolute purity.

Phoſphoric acid is produced by the *rapid* combuſtion of phoſphorus in oxygen, which may be done either over mercury or water. After combuſtion, which gives intenſe heat and light, the acid ſublimes in white cryſtalline flakes, that concrete on the inner ſurface of the veſſel, and which ſoon deliqueſce into a very ſtrong acid. If this is done over water, it ſhould be over a very thin ſtream of this fluid, and then by waſhing out the jar with it, all the acid mixes with the water, and may be concentrated by evaporation.

Another and very convenient way of preparing it is, by compleating the acidification of phoſphoreous acid by the nitric, as mentioned in the former article. Let phoſphoreous acid be prepared either by the ſlow combuſtion of phoſphorus, or elſe in the following way, which is very convenient. Put a quantity of pure phoſphorus in a ſmall cup, which will not crack by the heat, ſtanding in a plate, the bottom of which is covered with water: kindle it, and immediately whelm over it a large bell-glaſs, which, as in the combuſtion in oxygen, will ſpeedily be lined with the concrete acid. When the flame has gone out and the veſſel is cold, lift up the jar to change the air within it, and again fire the phoſphorus as before. When this has been repeated a number of times, waſh all the inſide of the jar with the water of the plate, and evaporate this in the open air till it begins to ſend forth bubbles which flaſh as they break; then add nitric acid till no more red nitrous vapours are perceived, and complete the evaporation nearly to dryneſs. The reſidue is pure phoſphoric acid. The oxymuriatic acid may be uſed inſtead of the nitric.

Phoſphorus alſo may be compleatly oxygenated by boiling with the nitric acid without the aſſiſtance of previous combuſtion, and this is perhaps the ſhorteſt and beſt way of preparing it. For this purpoſe put about ſix parts of moderately ſtrong nitric acid into a retort, heat it and then drop in one part of pure phoſphorus. A violent diſengagement of red nitrous vapour takes place, and when it has ceaſed, boil the liquor till all action between the two appears to be over. Then evaporate the ſolution nearly to dryneſs, and the reſidue is pure phoſphoric acid.

This acid may alſo be prepared from phoſphat of lime in conſiderable purity, by means of ſulphuric acid and *ammonia* in the way given by Dr. Higgins, and already mentioned under the article *Phoſphorus*.

It was found by Lavoiſier that 100 parts of phoſphorus, during combuſtion in oxygen gas, abſorbed 154 of oxygen, and produced 254 of concrete phoſphoric acid; which proportions have been confirmed, or nearly ſo, by other chemiſts.

Phoſphoric acid, in whatever way prepared, has the following properties: When concentrated as much as poſſible, retaining the liquid form, it is a thick unctuous-looking fluid of the ſpecific gravity of 2, or ſometimes more, ſtrongly acid but with no other taſte, nor any

ſmell. It is capable of the concrete form under certain circumſtances. When produced by combuſtion in the way already mentioned it appears in cryſtalline flakes but very deliqueſcent: the liquid acid alſo when of 2 ſp. gr. if kept for ſeveral days at 32° or thereabouts will gradually depoſit ſmall needled cryſtals.[a] Even in ſummer this takes place when quite at reſt, but in a longer time.

Phoſphoric acid is entirely unaltered and fixed in the fire. When the liquid acid is heated, it firſt parts with its water, then, continuing the heat, it becomes a clear gelatinous maſs, and at laſt when the heat is raiſed to redneſs it bubbles and ſwells, and finally ſettles into a clear colourleſs acid glaſs. This however is again ſoluble in water and returns to its former ſtate. The gelatinous acid is extremely deliqueſcent, and the vitreous acid in ſome degree, and by expoſure to air they both return to the ſtate of the unctuous liquid acid. The vitreous acid is a very powerful flux for all earthy and many metallic ſubſtances, and ſtrongly acts upon earthen crucibles, ſo that in fact it can hardly be obtained abſolutely pure, unleſs melted in a platina crucible. The phoſphoric and the boracic acids reſemble each other ſo ſtrongly in their unalterability in any fire, and their powerful action as a flux, that they have been thought to be the ſame ſubſtance under ſome modification; but no experiments have as yet confirmed this opinion.

This acid is not acted on by hydrogen or ſulphur, but charcoal decompoſes it entirely in a ſtrong heat, as is ſeen in the proceſſes for the preparation of phoſphorus deſcribed under that article.

The combinations of this acid with the ſeveral baſes are deſcribed in the following article.

PHOSPHATS and PHOSPHITES.

The ſalts formed by the union of the phoſphoric acid with the ſeveral baſes are called *Phoſphates*, thoſe with the phoſphoreous acid, *Phoſphites*. The former of theſe will be firſt deſcribed.

There are ſome circumſtances belonging to the phoſphates in general, which may be previouſly mentioned. They are all, except the phoſphat of ammonia, fixed in the fire, and readily run into a glaſs by a red heat. The phoſphat of ammonia loſes entirely its alkali, and when kept in fuſion for a little time pure phoſphoric acid is left.

A remarkable circumſtance in which the phoſphats differ from the ſulphats, is, that the former are not decompoſed by calcination with charcoal, which ſeems to have no effect on them. The phoſphoric acid however is compleatly decompoſed by this method, and alſo the phoſphat of ammonia, but the latter only on account of the volatilization of the alkali, which leaves the acid naked. Hence phoſphorus can be made directly only from the phoſphoric acid or phoſphat of ammonia.

With many of the baſes this acid unites in more than one proportion, forming with the ſame alkali and the ſame acid, ſalts differing extremely in ſolubility and ſenſible qualities.

Many of the other acids decompoſe the phoſphats partially or totally.

PHOSPHAT OF POTASH.

When phoſphoric acid and potaſh are in mutual ſaturation, a ſalt is produced which is uncryſtallizable, but when evaporated ſufficiently paſſes into the ſtate of a thick jelly which is deliqueſcent in the air. It is therefore extremely and almoſt indefinitely ſoluble in water; when heated it ſwells and bubbles till it has parted with its water, after which it melts into a clear colourleſs glaſs. It is decompoſed by the ſulphuric, nitric, and muriatic acids, and by lime, barytes, and ſtrontian, ſo that if a little lime-water, for example, be dropped into a ſolution of this, or any other alkaline phoſphat, a white precipitate of phoſphat of lime takes place. Its conſtituent parts are not known, nor is it uſed.

Sub-Phoſphat of Potaſh. This variety was firſt noticed by Darracq,[b] and occurred in repeating ſome experiments on the ſuppoſed decompoſition of the alkalies. On heating to vitrification a mixture of two parts of oxymuriat of potaſh with one of phoſphoric acid, and digeſting the maſs in cold water, a white inſoluble granular ſubſtance is left, which was miſtaken for phoſphat of lime, but is in reality the phoſphat of potaſh in queſtion. By evaporating the ſolution and again calcining, more of this granular ſubſtance is left behind on digeſtion with water, and thus by four or five proceſſes the whole is converted to this phoſphat.

The ſame ſalt may alſo be produced in a ſhorter way by fuſing in a platina crucible neutralized phoſphat of potaſh with an exceſs of potaſh.

This ſub-phoſphat is inſoluble in cold water, but diſſolves in a ſmall degree with a boiling heat. It is extremely fuſible and melts before the blow-pipe into a perfect bead of glaſs, which is tranſparent whilſt in fuſion, but becomes

[a] Guerſen in Phil. Mag. vol. 17.

[b] An. Chim. tom. 40. p. 177.

opake on cooling. The proportions of its constituent parts are not known.

PHOSPHAT OF SODA.

This salt is now the best known of the alkaline phosphats, having been introduced in pharmacy by Dr. Pearson as a very useful purgative. It may be prepared in several ways. The simplest, but by much the most expensive (and therefore never used in quantity) is first to prepare phosphoric acid by the combustion or oxygenation of phosphorus, and then to add carbonat of soda in excess, to evaporate, and crystallize. This salt is however actually prepared by adding carbonat of soda to the phosphoric acid (or rather the acidulous phosphat of lime) procured by decomposing bone-ash by sulphuric acid. The method of making this decomposition has been described under the article phosphorus, and will be further noticed when treating of *Phosphat of Lime*.

To obtain this salt pure, the sulphuric acid should not be more than is sufficient to decompose the bone-ash, and the sulphat of lime should be allowed to precipitate by cooling (after concentration of the acid liquor) before the alkali is added. The acid liquor is then to be diluted with sufficient water, and carbonat of soda added till there is a very sensible excess of alkali, after which the solution is to be evaporated considerably and set by to crystallize. The phosphat of soda then separates in large well defined crystals, generally rhomboidal or prismatic.

The mother water is then to be again evaporated, adding either soda or phosphoric acid, according as it is too little or too much alkaline, and a fresh crop of crystals is obtained.

This salt naturally contains and requires an excess of soda, for when merely saturated it will not crystallize.

The quantity of phosphat of soda obtained in general is about equal to the carbonat of soda employed.

Another and perhaps a cheaper way of preparing this salt, is given by Mr. Funcke, a German chemist.[c] Add to bone-ash, diffused in water, just enough dilute sulphuric acid to saturate the carbonat of lime which it always contains in small proportion, which is known by the cessation of the effervescence. Then dissolve the whole in nitric acid and add to the solution as much sulphat of soda as the quantity of bone-ash used. Distill the whole to dryness, to recover the nitric acid, and the residue in the retort is a mixture of phosphat of soda and sulphat of lime, formed by the mutual decomposition of the phosphat of lime and the sulphat of soda. The phosphat of soda is then separated by solution and crystallization in the usual manner. It is obvious however that if too much sulphat of soda be added, the excess must mix with the phosphat of soda. This admixture of sulphat of soda may be detected by nitrat or muriat of barytes, which forms a white precipitate with both salts, but the phosphat of barytes is again decomposed, and forms a clear solution with nitric or muriatic acid, whilst the sulphat of barytes remains untouched.

Phosphat of soda has a simply saline taste without any thing nauseous or bitter (in which it differs from many other of the purgative salts) it shews with vegetable colours the marks of excess of alkali, it effloresces in the air, but only on its surface.[d]

It is one of the most soluble of the non-deliquescent salts, requiring no more than four parts of cold water, and two of boiling, whence it easily crystallizes from its hot saturated solution on cooling. It is composed according to Thenard[e] of 66 per cent. of water of crystallization, 15 of phosphoric acid, and 19 of soda, as determined from the following facts, namely, that 100 parts lose 66 on calcination, and the residue decomposed by muriat of lime give 33 of phosphat of lime, of which the acid is estimated at 15.

When heated, this salt melts in its own water, bubbles and boils up, and at last, when red hot, it subsides into a glass which before the blow-pipe is clear when hot, but on cooling grows opake, and assumes nearly the form of the garnet. This singular property it has in common with the phosphat of lead.[f]

The sulphuric, nitric, and muriatic acids decompose it only partially, leaving in the solution an acidulous phosphat of soda. The same is produced by adding phosphoric acid, and this salt is extremely soluble, scarcely crystallizable, and takes the form of small soft brilliant threads, like boracic acid.[g]

The phosphat of soda, besides its use in medicine, has been employed with some success as a substitute for borax, in the soldering of metals.

PHOSPHAT OF AMMONIA.

This combination is found in tolerable abundance in urine, but united with phosphat of soda, from which it is scarcely possible to separate it, and therefore to obtain it pure, it must be formed by the direct union of its two in-

[c] Phil. Journ. vol. 6. from Scherer's Journal. [d] Pelletier. [e] An. Chim. tom. 39. [f] Pelletier. [g] Fourcroy.

gredients. For this purpose saturate the acid liquor (arising from the decomposition of bone-ash by sulphuric acid) with pure ammonia, which will separate the phosphat and sulphat of lime, and the clear liquor contains the pure phosphat of ammonia, if no excess of sulphuric acid has been employed. If carbonat of ammonia instead of pure ammonia be used, some of the phosphat of lime remains in solution, which however may be got rid of by evaporating the clear liquor nearly to dryness, and redissolving in cold water. The filtered solution must then be supersaturated with ammonia carbonated or pure, and gently evaporated to the crystallizing point.

The form of this salt is a four-sided prism terminated pyramidally. When the alkali is not in excess it runs into small indeterminate needles. The taste is sharp and cooling.

This salt dissolves in four parts of cold water and in somewhat less of boiling, but not so much as to crystallize by simple cooling without further evaporation.

When heated, it melts, loses first its water with a portion of its alkali, and then the rest of the ammonia flies off, and nothing but pure phosphoric acid is left. Hence it is that this is the only one of the phosphats from which phosphorus can be procured, as in fact, after it is red-hot, it is simply phosphoric acid.

The sulphuric, nitric, and muriatic acids decompose this salt entirely.

Phosphat of ammonia is used considerably as a flux for earths and oxyds, especially in experiments with the blow-pipe. It becomes in these cases only a convenient mode of applying phosphoric acid, as the alkali is totally expelled.

Phosphat of Soda and Ammonia. *Microcosmic salt*, or *Fusible salt of Urine*.

When any liquid containing phosphoric acid, soda and ammonia (such as urine is) is evaporated and its saline contents obtained by crystallization, these two phosphats, or a portion of one or other of them, unite in a triple salt, which is the one in question. It will be further noticed under the article *Urine*, whence it was at first obtained, but some of its properties may be mentioned in this place.

It seems to have no very uniform proportions of ingredients, for as Fourcroy observes, the quantity of ammonia is constantly diminishing by successive solutions and crystallizations, and the acid to which it was united remains, rendering therefore the remaining salt more and more acidulous; and by long exposure to the air the whole ammonia is lost. This salt when first prepared has an excess of acid so as to turn syrup of violets green. It effloresces in the air. Distilled per se it gives an ammoniacal water, and a little phosphat of ammonia also rises. Fourcroy estimates the proportions in 100 parts of this salt to be as follows: viz. of phosphoric acid 32; of soda 24; of ammonia 19; of water 25.

Phosphat of Barytes.

When any alkaline phosphat is dropped into a solution of any barytic salt, a heavy white powder subsides, which is the phosphat of barytes. The same may also be prepared by digesting phosphoric acid with carbonat of barytes, or adding this acid to barytic water.

This salt is insoluble in water either hot or cold, and even in phosphoric acid. The sulphuric, nitric, and muriatic acids decompose it by simple elective attraction.

It is fusible at a high temperature, and when kept melted on charcoal by the blow-pipe it gives a yellow phosphoric flame.[a]

It is not used.

Phosphat of Strontian.

This salt may be prepared like the former either by double decomposition of the earthy muriat or nitrat, or by the direct union of the constituent parts. It is in the form of a white heavy powder, entirely insoluble in water, but it differs from the former salt in being soluble in an excess of phosphoric acid. Before the blow-pipe on charcoal it melts and gives a purple flame.

It is entirely decomposed by the sulphuric acid, but only partially by the nitric and muriatic acids, and an acidulous phosphat of strontian is left. In this it differs from the phosphat of barytes. It is composed according to Vauquelin of 48.76 per cent. of strontian, and 41.24 of phosphoric acid.

Phosphat of Lime.

This is by far the most important of the earthy phosphats, and is that which has been examined with the most attention.

It is found native both as a mineral and as a constituent part of a number of animal organs and fluids. The mineral phosphat of lime is described under the article *Apatit*, of which there are several varieties in the animal kingdom. Phosphat of lime is contained most copiously in *Bone*, as has been fully detailed under that article.

It also forms the ash or earth that remains

[a] Vauquelin.

after every ſoft animal organ has undergone the utmoſt effect of fire; and it may be detected in ſolution in a great variety of animal fluids.

There are at leaſt two ſtates of phoſphat of lime which ſhould be well diſtinguiſhed. One is that in which the conſtituent parts are fully neutralized ſo as to ſhew no marks of exceſs either in acid or baſe, and in this ſtate it is a white powder, perfectly inſoluble in water, nearly infuſible, and in appearance reſembling a ſimple earth. This is the ſtate in which it exiſts in bone-aſh, of which indeed it forms by far the greateſt part, and was formerly called the *earth of bones*.

The other ſtate which has been known much later, and which has never been found native, but is only known in the laboratory, is that in which the acid is greatly in exceſs, and may be here termed *ſuper-phoſphat of lime*. It was firſt detected in the acid liquor that is produced by decompoſing bone-aſh by ſulphuric acid, is acid to the taſte, and in a red heat readily melts into a porous glaſs. It was at firſt miſtaken for pure phoſphoric acid. It is not certain however whether the proportion of phoſphoric acid in this ſpecies is conſtant, or whether it does not admit of an indefinite variety.

We ſhall firſt deſcribe the common or neutral phoſphat.

Phosphat of Lime may be obtained quite pure either by ſaturating the pure acid with marble and then evaporating; or by waſhing bone-aſh with hot water to diſſolve out any ſoluble ſalt which it may contain; then adding a little acetous or dilute muriatic acid till the effervеſcence ceaſes to engage the carbonat of lime which it contains, and again thoroughly edulcorating.

This phoſphat of lime is infuſible *per ſe* in the moſt intenſe heat, the utmoſt effect of fire being only to reduce it to a porcellarious frit. With vitreſcent mixtures it makes glaſſes of difficult fuſibility, and more or leſs opake, as deſcribed in the article *Glaſs*.

It is entirely inſoluble in water hot or cold.

All the acids, even the carbonic, act upon it without difficulty; but probably in a different manner. If ſulphuric acid is digeſted with a very ſmall quantity of phoſphat of lime a clear ſolution is effected, which contains ſulphat of lime, and the *acidulous* or *ſuper-phoſphat* of lime, and naked phoſphoric and ſulphuric acid. The latter acid therefore partially decompoſes the phoſphat; and the ſuper-phoſphat, together with the ſulphat of lime thereby produced, diſſolves in the exceſs of acid.

When the proportion of phoſphat of lime is greater, the ſame decompoſition takes place, only the greater part of the reſulting ſulphat of lime remains undiſſolved, as is the caſe in the common treatment of bone-aſh with ſulphuric acid.

It is aſſerted by Vauquelin[i] that the nitric and muriatic, and ſome other acids, act in the ſame manner on the phoſphat of lime, and partially decompoſe it. It is not eaſy however to demonſtrate this, for when phoſphat of lime is digeſted with theſe acids, the nitric for example, a clear ſolution is made, (every product being ſoluble whatever be the mutual action of theſe ſubſtances) ſo that the ſolution may either contain phoſphat of lime ſimply diſſolved undecompoſed by theſe acids, or it may conſiſt of ſuper-phoſphat of lime, nitrat of lime, and nitric acid in exceſs. On adding an alkali, pure or carbonated, to the ſolution, a white precipitate falls down, which is phoſphat of lime as before, but it is obvious that the action of the alkali may be either ſimply to precipitate the phoſphat of lime by ſuperior affinity with the nitric acid; or, firſt to ſaturate the exceſs of phoſphoric acid in the ſuper-phoſphat, and thus to bring it to the ſtate of neutral phoſphat, and then to precipitate it by engaging the acid which held it in ſolution. If a pure alkali is uſed in this caſe the whole of the phoſphat falls down; if a carbonated alkali, a part of the phoſphat remains in ſolution by the help of the carbonic acid. Hence it may be inferred, (which is the fact) that even carbonated water will diſſolve phoſphat of lime.

Phoſphat of lime is produced alſo by double decompoſition, on dropping a ſolution of any phoſphated alkali into any ſoluble calcareous ſolution that has not any great exceſs of acid. Vauquelin alſo found[k] that on boiling phoſphat of ſoda with wet and newly precipitated carbonat of lime, the ſame reſult took place, and carbonat of ſoda with phoſphat of lime were produced.

The oxalic acid added to phoſphat of lime diſſolved in any weak acid ſeparates almoſt the whole of the lime in the form of oxalat of lime, and oxalat of ammonia appears to ſeparate the whole. From analogy it is probable that ſulphat of ammonia would have the ſame effect.

The proportion of ingredients in this phoſphat as forming bone-aſh, are ſtated by Vauquelin to be 41 per cent. of phoſphoric acid and 59 of lime. But the phoſphat formed

[i] Fourcroy Syſteme.

[k] Journ. des Mines, No. 37. p. 25.

by saturating phosphoric acid (arising from the oxygenation of phosphorus by combustion and nitric acid) with marble, is stated by Klaproth[l] to contain only 30.5 per cent. of acid.

The uses of phosphat of lime are mentioned under the article *Bone*.

Super Phosphat of Lime, or *Acidulous Phosphat*.

The preparation of this salt from bone-ash and sulphuric acid has been particularly mentioned under the article *Phosphorus*, being that acid substance which was generally mistaken for pure phosphoric acid till the nature of this salt was explained.

When distilled with charcoal all the excess of acid, which makes the difference between the neutral and the super-phosphat, is decomposed by the charcoal and yields phosphorus in proportion, and the neutral phosphat remains in the retort.

The proportion of acid to lime, however, appears to vary considerably, for Berthollet[m] found that on washing with water the super-phosphat deposited during the concentration of the solution from bone-ash and sulphuric acid, it resolved itself into two portions, one of which dissolved in the water and the other not.

This super-phosphat of lime is prepared with most accuracy by digesting phosphat of lime in phosphoric acid till it is saturated. This solution yields the salt by evaporation in the form of small shining scales or filaments[n] which have almost a gelatinous consistence, and a very sour taste. This is the state in which the phosphat of lime is contained in fresh urine. This salt is somewhat deliquescent, is soluble in water, more in hot than cold, so as to crystallize by cooling. When heated it melts, swells, and finally vitrifies at a moderate red heat. The glass is opake till the fusion is compleat, and it then becomes clear, so that opacity is not a constant sign of the presence of lime, as has been supposed. This glass is not in the least deliquescent, is insipid, and insoluble in water, in all which circumstances it differs from the vitreous phosphoric acid. Charcoal decomposes it after being vitrified, as much as before, but probably with more difficulty.

The acids probably do not act upon this salt except simply to dissolve it. All the alkalies and earths reduce it to the state of neutral phosphat by saturating the excess of alkali, and cause the phosphat to precipitate.

If a large quantity of alcohol is added to a solution of the super-phosphat of lime it takes up much of the excess of acid, without a proportional quantity of the lime; so that the remainder is left in a state more approaching to the neutral phosphat.

The composition of this salt when prepared by phosphoric acid and phosphat of lime, according to Vauquelin, is 54 per cent. of phosphoric acid and 46 of lime, and of this quantity of acid, about 32 parts are required to saturate the lime in the proportions belonging to the neutral phosphat, leaving therefore 22 parts of excess of acid, which alone can be decomposed by charcoal. Hence, according to this estimation, 100 parts of the acidulous phosphat will yield no more phosphorus than can be obtained from 22 parts of pure phosphoric acid.

Phosphat of Magnesia.

This salt may be prepared either by saturating phosphoric acid with carbonat of magnesia and evaporating to the crystallizing point; or by double decomposition, by adding phosphat of soda to the sulphat or any other salt of magnesia. When the two latter are added in a considerably concentrated solution, after some hours the phosphat of magnesia deposits in transparent and irregular crystals, and the clear liquor contains sulphat of soda.

This salt requires 50 parts of cold water for its solution, but less of boiling water. The sulphuric, nitric, and muriatic acids, decompose it entirely, as do the fixed alkalies, lime, barytes, and strontian, but ammonia only partially, forming a triple salt.

Phosphat of magnesia melts in a red-heat into a perfect glass.

It is not used.

It is contained naturally in urine.

Phosphat of Ammonia and Magnesia.

This triple combination was discovered by Fourcroy in a calculus found in a horse's intestine, and since that time it has been detected in the bones of most animals in small quantity. The mode of analysis is described under the article *Bone*. It is formed directly by adding phosphat of ammonia, or ammonia, or its carbonat to phosphat of magnesia; and it also is deposited by adding phosphat of soda to any triple ammoniacal salt of magnesia. On this fact Dr. Wollaston has suggested a convenient way of separating and estimating magnesia when in solution, with or without other earths in any acid, which may be here mentioned.

Add to the solution in muriatic acid (for

[l] Anal. Essays vol. 2. p. 164. [m] Chemical statics. [n] Vauquelin. [o] Berthollet.

example) ſome ſuper-carbonat of ammonia, (made by expoſing the common carbonat to the air till it loſes its ſcent) which will ſaturate the acid and precipitate the other earths, but not the magneſia, being held diſſolved by the exceſs of carbonic acid. To the ſolution (which now contains muriat of ammonia and carbonat of magneſia,) then add a cold ſaturated ſolution of phoſphat of ſoda, and in a very ſhort time the whole will be turbid with a white powder, which ſoon ſubſides, and is the *ammoniaco-magneſian phoſphat*.

Dr. Marcet[p] eſtimates 100 grains of this ſalt dried at 100° to contain 19 of magneſia.

This triple ſalt is ſcarcely ſoluble in water, in which reſpect it differs remarkably from the ſimple phoſphat of magneſia. By heat the ammonia flies off, and it is reduced to the ſimple phoſphat.

On diſtilling it with charcoal it gives a little phoſphorus, owing to the decompoſition of that part of the phoſphoric acid which exceeds the proportion belonging to the ſimple phoſphat of magneſia in a given quantity of the ſalt.

The ſtronger acids compleatly decompoſe it, and naked phoſphoric acid is left in the ſolution. The fixed alkalies and alkaline earths alſo decompoſe it, but by expelling the ammonia and uniting to the acid, in which caſe the magneſia is left uncombined.

PHOSPHITES.

Theſe ſalts reſult from the combination of the *Phoſphoreous* acid (already deſcribed) with the ſeveral baſes, and were frequently confounded with the phoſphats, owing to the indiſcriminate uſe of the acid reſulting from the ſlow combuſtion of phoſphorus and of the fully oxygenated acid, till their characteriſtic properties were pointed out in a ſeries of experiments undertaken by Vauquelin, and publiſhed in the Journal de l'École Polytechnique.[q]

The phoſphites have ſome properties in common by which they may be particularly diſtinguiſhed from the phoſphats. The moſt ſtriking of theſe is that they all yield a ſmall quantity of phoſphorus by diſtillation without addition, and when melted by the blow-pipe even on an incombuſtible ſupport, they give out a very brilliant light, owing to the exceſs of phoſphorus burning off.

Theſe ſalts alſo precipitate gold from its ſolutions in a metallic ſtate, and detonate by percuſſion when mixed with oxymuriat of potaſh.

Their taſte alſo is not ſimply ſaline like the phoſphats, but is mixed with ſomething pungent and alliaceous.

It would be ſuppoſed from analogy with the ſulphites, that the phoſphites would ſtill more rapidly than the latter ſalts, abſorb oxygen from the air ſufficient to compleat their acidification, conſidering the great eaſe with which the firſt degree of acidification takes place in the air. The contrary however takes place, for the ſolutions of the phoſphites may remain for months in full contact with the atmoſphere before this change takes place, whereas the ſame change takes place in the ſulphites in a few days in ſimilar circumſtances. This difference is ingeniouſly explained by Vauquelin on the known principle in chemical affinity, that any decompoſition is favoured by adding to the ſubſtances in action any body with which the new compound has an affinity, and of courſe the ſtronger this affinity is, the more readily will the decompoſition take place. Thus in the inſtances here mentioned, the compleat oxygenation of the *phoſphoreous* acid in the phoſphite is favoured by the affinity of the *phoſphoric* acid (when produced) with the alkaline or earthy baſis preſent, and the ſame with the *ſulphureous* and *ſulphuric* acid. But both the actual affinity of the ſulphuric acid with theſe baſes is ſtronger than that of the phoſphoric, and the difference between the affinity of the ſulphuric and the ſulphureous acids for the ſame baſes is greater than that between the phoſphoric and phoſphoreous, and it is probably from this cauſe that the compleat oxygenation of the ſulphites is ſo much quicker than that of the phoſphats.

All the phoſphites are readily changed to phoſphats, either by applying a red heat, which burns off the exceſs of phoſphorus, or by treating with nitric or muriatic acid, which compleats their acidification.

The alkaline phoſphites can only be prepared by the direct combination of the baſe with the phoſphoreous acid, and not, (like the ſulphites from the ſulphats) by deoxygenation of the phoſphats by carbonic matter.

The individual phoſphites may be briefly noticed.

PHOSPHITE OF POTASH.

This ſalt eaſily cryſtallizes on cooling a hot ſaturated ſolution of it, and takes the form of a four-ſided priſm with a dihedral ſummit.

It is ſoluble in three parts of cold water and leſs of boiling. When heated to redneſs the exceſs of phoſphorus burns off, and the reſidue which is an opake glaſs, is ſomewhat alkaline.

[p] Analyſis of Brighton Water.

[q] 4th Cahier. p. 655.

It is composed, according to Vauquelin, of 49.43 per cent. of potash; 39.47 of phosphoreous acid; and 11 of water of crystallization.

PHOSPHITE OF SODA.

This salt is prepared like the last-mentioned, but chiefly by the help of evaporation. Two parts of cold water dissolve it, and somewhat less of boiling. The solution gently evaporated, deposits the salt generally in the form of feathery crystals like sal-ammoniac.

It is composed of 23.68 of soda; 16.32 of phosphoreous acid; and 60 of water.

PHOSPHITE OF AMMONIA.

This salt has a strong pungent taste, crystallizes in long transparent needles that climb the sides of the vessel that contains the solution; is soluble in two parts of cold water, and much less of boiling.

When heated before the blow-pipe on a metal spoon, it swells, boils, and in a few seconds gives out a great quantity of phosphuretted hydrogen gas, which takes fire in the air, with its usual appearance of a circular wreath of smoke. Distilled in a retort, liquid ammonia is first disengaged, which is succeeded by subphosphuretted hydrogen, which is luminous in the air, but does not inflame like the former, and finally pure phosphoric acid is left in the retort.

This salt added to nitrat of mercury precipitates a white phosphite of mercury, which turns grey in the light.

Phosphite of ammonia is decomposed by the fixed alkalies, and alkaline earths, which unite with the acid and disengage ammoniacal vapours.

It is composed of 51 per cent. of ammonia, 26 of phosphoreous acid, and 23 of water.

PHOSPHITE OF LIME.

Phosphoreous acid added to lime-water forms a white precipitate, which is the phosphite of lime. This is insoluble in water except with an excess of acid, in which case it may be obtained by evaporation in hard minute crystals. This salt is decomposed by most of the mineral acids, and by those vegetable ones that produce an insoluble salt with lime, such as the oxalic, citric, and tartareous. Phosphite of lime is composed of 51 per cent. of lime; 34 of acid; and 15 of water.

PHOSPHITE OF BARYTES.

This, like the former is insoluble in water without addition, though not absolutely so, since when digested in water, lime water added to the clear liquor causes a cloudiness, owing to the decomposition of the phosphite of barytes, and formation of phosphite of lime. The solubility of phosphite of barytes much increases by an excess of acid. This salt is decomposed by oxalic acid, which forms a crystalline deposit of oxalat of barytes after remaining with it for a time.

When phosphite of barytes is heated by the blow-pipe it becomes luminous, as all the phosphites do, but in this instance the light is so dazzling that the eye cannot safely bear it.

It is composed of 51.23 per cent. of barytes; 41.77 of phosphoreous acid; and 7. of water.

PHOSPHITE OF MAGNESIA.

This salt, like the last, is scarcely soluble except with excess of acid. It is composed of 20 of magnesia; 44 of acid; and 36 of water. The fixed alkalies and the alkaline earths decompose it entirely, but ammonia only partially, and forms with the remainder a triple salt.

PHOSPHORUS *Cantons* } See
PHOSPHORUS *Baldwins* } PHOSPHORI.

PHOSPHORI.

In the preceding description of Kunckel's phosphorus we have mentioned that when exposed to the air at the common temperature, it gives out a very considerable quantity of light without any sensible emission of heat. Now there are many substances which, however different from common phosphorus in other respects, agree with it in presenting the above phenomenon under particular circumstances, on which account they are all popularly classed together under the general term *Phosphori*. Of these we shall now proceed to mention the principal facts that have been as yet discovered.

There are three leading divisions of phosphorescent substances.

The first comprehends those which require a previous exposure to the solar or other light in order to become luminous; whence they are called *Solar phosphori*.

The second includes those which without any necessary previous exposure to light become luminous when moderately heated; *Phosphori from heat*.

The third includes those substances, belonging to the animal and vegetable kingdoms, which emit light spontaneously at the common temperature without the necessity of previous exposure to light; *Spontaneous phosphori*.

§ 1. *Solar phosphori*.

A casual discovery by Vincenzio Cascariolo, a shoe-maker of Bologna, about 1630, was the first circumstance that attracted the notice of philosophers to this curious subject. This man being in quest of some alchemical secret was induced to calcine a parcel of Bolognian

spar, (a subspecies of HEAVY SPAR, or native sulphat of barytes) which he had procured from Monte Paterno in the neighbourhood of the city; and observed that whenever this substance thus prepared was placed in a dark room, after having been exposed to the sun, it continued to emit faint rays of light for some hours afterwards. In consequence of this interesting discovery the Bolognian spar came into considerable demand among natural philosophers, and the curious in general, so that the best method of preparing it became an object of even some pecuniary importance. The family of Zagoni were the most successful in this pursuit, and in consequence furnished large quantities of *Bolognian phosphorus* to all parts of Europe till the subsequent discovery of more powerful phosphori put an end to their monopoly. The particular process employed by the Zagonis is not known, but we learn from Kircher that if the mineral is finely pulverized and then beaten up into a paste with white of egg or linseed oil, and calcined in the open fire, it will after exposure for a minute to the light exhibit its phosphorescent quality. Many years afterwards Marggraaf in analysing other varieties of sulphated barytes found that they were all capable of being made into phosphori by forming them, when pulverized, into thin cakes with gum tragacanth or other mucilage, and then carefully calcining them at a red heat. Some management however is requisite in conducting the calcination that it may be neither too much nor too little, by either of which faults the luminous quality is very materially injured.

In the year 1677, or nearly half a century after the discovery of the Bolognian phosphorus, G. A. Baldwin, a native of Misnia, observed that if nitrat of lime was evaporated to dryness and then formed into a compact mass by fusion at a red heat, it would exhibit the same property of imbibing and emitting light as the former only somewhat inferior in degree; hence this preparation obtained the name of *Baldwin's phosphorus*.

No other discovery of much moment was made on this subject till the year 1730, when M. du Fay, so celebrated for his electrical researches, turned his attention that way. He observes that all earthy substances susceptible of calcination either by mere fire or when assisted by the previous action of nitrous acid, possessed the property of becoming more or less luminous when calcined and exposed for a short time to the light. Those that exhibited this quality in the greatest perfection were found to be limestone and many other kinds of carbonated lime, gypsum, and particularly the topaz; some diamonds were also observed to be luminous by simple exposure to the sun's rays without being previously ignited; but flint, sand, jasper, agate, and rock-crystal, were found to be incapable of becoming phosphorescent.

Shortly after these interesting discoveries of M. du Fay the subject was taken up by Becaria[a], who greatly enlarged the list of phosphorescent substances and found that a vast variety of bodies were convertible into phosphori by the mere light of the sun; this he observed to be particularly the case with regard to the different varieties of carbonat and sulphat of lime, organic animal remains, and geodes lined with minute crystals of quartz; most compound salts when clear and crystallized, particularly Glauber's salt, nitre, and borax, were also found to be phosphorescent; of vegetable substances, all the farinaceous and oily seeds, all the gums and several of the resins, the white woods, and vegetable fibre either in the form of paper or linen, also starch, and loaf sugar, proved to be good phosphori after being made thoroughly dry and exposed to the direct rays of the sun; sundry animal matters by a similar treatment were also converted into good phosphori, particularly bone either fresh or calcined, sinew, glue, hair, horn, hoof, feathers, and shells of fish. He also discovered that this property might be communicated to rock crystal and some of the gems by rubbing them against each other so as to roughen their surface, and then placing them for some minutes in the focus of a lens by which the rays of light were concentrated upon them at the same time that they were also moderately heated.

In the year 1768, Mr. Canton[b] contributed some important facts relative to solar phosphori, and communicated a method of preparing a very powerful one, which after the inventor is usually called *Canton's phosphorus*. It is thus made. Calcine oyster shells in the open fire for half an hour, then select the whitest and largest pieces and mix them with flowers of sulphur in the proportion of one part of the latter to three parts of the former, pack the whole closely into a crucible, lute on a cover, and heat it pretty strongly for one hour; when the crucible has again become quite cold turn out its contents, and select the whitest pieces for use.

[a] Act. Bologn. 1744—1747.

[b] Phil. Trans. lviii. p. 337.

The laſt perſon who has paid much attention to the ſubject of ſolar phoſphori is Mr. B. Wilſon, by whoſe very able experiments ſome important errors of Becaria have been rectified and to whom the diſcovery is due of the ſimpleſt and moſt powerful of all the phoſphori belonging to this claſs. *Wilſon's phoſphorus* is thus prepared. "Select a ſcore of oyſter ſhells, the thicker they are the better, then take moſt of the flaming coals, but not all of them, off a fire that is burning briſkly, ſtrew the ſhells over the ſurface and replace the coals that have been taken off. In about an hour's time take out the calcined ſhells obſerving to break them as little as poſſible, and after expoſing them for a few minutes to the light they will be found to have acquired a high degree of phoſphoreſcence glowing in the dark in a very beautiful manner, with moſt of the priſmatic colours. It is not however abſolutely neceſſary that the ſhells ſhould be calcined in the open fire, for if they are heated ſufficiently in a cloſe crucible they will exhibit priſmatic colours, chiefly blue and green, though not ſo bright as by the former method. If the calcination is effected in an iron crucible, all thoſe parts of the ſhells that are in contact with the ſides of the crucible will glow with a red light. The contact of inflammable matter, and particularly charcoal, with the ſhells during their calcination appears eminently to contribute to the brilliancy of the phoſphorus; hence it is that if the ſhells are calcined in a crucible in contact with thin plates of ſteel, the phoſphorus thus produced will be much more bright and of more various colours than where plates of iron are employed; and on the other hand if flat pieces of charcoal are made uſe of, the intenſity of the colours, eſpecially the blue, green, and red, is far greater than in thoſe produced by the ſteel.

In conducting experiments on ſolar phoſphori, as the light from many of them is very evaneſcent, ſome contrivance is neceſſary that they may be preſented to the eye immediately on their removal into the dark, all other light being at the ſame time carefully excluded. For this purpoſe it is convenient to have a ſmall cloſet painted black on the inſide, and with a black curtain hung up before the door; the window of the cloſet ſhould be accurately cloſed with a wooden ſhutter lined with black cloth and a thick curtain of the ſame colour. In the ſhutter ſhould be a ſmall ſlider through which a perſon within the cloſet may expoſe any ſubſtance to the light, at the ſame time that the interpoſed curtain prevents any external rays from reaching the eyes of the experimenter, by which even the weakeſt degree of phoſphoreſcence will ſcarcely eſcape his obſervation. Laſtly, to provide for a due ſupply of freſh air, two pieces of curved pipe made of any opake material ſhould be fixed in the door, the one at the top and the other near the bottom. In a room thus conſtructed the following appearances may be perceived.

Any of the phoſphori mentioned above, after expoſure to the light for half a minute or leſs, being introduced into the cloſet, will be obſerved to emit light for a longer or ſhorter time, becoming by degrees more and more dim till their luminouſneſs entirely ceaſes. To produce this quality in ſome the direct rays of the ſun are neceſſary, but in others, particularly the calcareous and barytic phoſphori, the common light of day is quite ſufficient; in all however the light is greater when the weather is dry and warm, than when it is cold and wet. The colour of the light in moſt caſes is white or reddiſh white, but in Wilſon's phoſphorus not only white but all the priſmatic colours make their appearance, ſometimes being all united in a ſingle ſpecimen, at other times each piece exhibiting only one or two colours. In every ſpecies of ſolar phoſphorus the light after having been extinguiſhed may be renewed for any number of times without the ſmalleſt apparent diminution of brilliancy by ſimple re-expoſure for a few ſeconds to the light.

If while the phoſphorus is preſented to the light it is moderately heated, its luminouſneſs will by this means be very ſenſibly augmented. Thus if a common box ſmoothing iron heated in the uſual manner be placed for half a minute on a ſheet of dry white paper, and the paper be then expoſed to the light, and afterwards examined in the dark cloſet, it will be found that the whole paper will be luminous, that part however on which the iron had ſtood being much more ſhining than the reſt.

The effects of a variation in temperature on phoſphori *after* having been expoſed to the light are alſo very remarkable. If a thin glaſs tube be filled with Canton's or Wilſon's phoſphorus, and, as ſoon as it is brought into the dark cloſet, be plunged half way into a freezing mixture for a few minutes, it will be found on again withdrawing the tube that the cold portion is much leſs luminous than the other, and if the freezing mixture has been ſufficiently powerful, it will be entirely extinguiſhed. This

* Wilſon on Phoſphori, p. 20.

however is by no means an exhaustion but only a suspension of the luminous property, for as the dark part of the tube begins to acquire the temperature of the surrounding air its light will return, and it will continue to shine longer than the other part of the tube in proportion to the time that it was kept in the freezing mixture. Hence it may be inferred, that at a very low temperature the present class of solar phosphori would cease to exist.

As cold retards so heat quickens the emission of light from phosphoric substances. Thus if the tube mentioned in the last paragraph, be dipped half way into boiling water, a great increase of brightness will be perceived in the immersed portion, which in a minute or less will be succeeded by entire darkness, while the part not heated will shine much longer, though with less splendor.

If any of these phosphori after having been kept in the dark till it is totally extinguished, be placed (without any further exposure to the light) in the warm hand, its luminousness will be for a short time renewed; if after the warmth of the hand has ceased to produce any effect, it be placed in boiling water, a further emission of light will take place, and finally it may be entirely exhausted of its light by being placed on a metallic plate, heated nearly to redness. Hence it appears that there are two causes of the extraordinary brightness exhibited by solar phosphorus when strongly heated immediately on being introduced into the dark room; in the first place there is a greater quantity of light actually given out, and, secondly, the whole is discharged in perhaps a twentieth of the time in which even a part would be exhausted at the common temperature.

With regard to the origin of the light in these substances there are two theories. According to the one it is simply the solar light which has been previously imbibed by them; and according to the other it is the inherent light of the phosphoric substance itself. In favour of the first hypothesis it may be observed that the phosphorescence cannot take place without previous exposure to the light, and that the period of its greatest brilliance is the moment of its being placed in the dark, whence it regularly and rapidly diminishes till it is totally extinguished. But the strongest proof of the truth of this theory is an experiment related by Becaria, in which he affirms, that those phosphori which under the usual circumstances emit a white light, give out coloured rays in the dark, corresponding to those which they receive from the sun, with the interposition of a plate of coloured glass. Many doubts however have arisen as to the accuracy of the fact here mentioned. Du Fay's experiments made before those of Becaria, lead to a directly opposite result, the light emitted by the phosphorus being of the same tint whatever was the colour of the glass through which the rays passed to the phosphorus. In like manner M. Bourriot on repeating the experiments of Becaria, entirely failed in producing the effects said by the latter to have taken place; nor was M. Magellan more successful. Mr. Wilson has examined this part of the subject considerably at length, with the following results.[a] A piece of prepared oyster shell which by exposure to the common light gave out a white light was at different times placed in the solar rays with the interposition of a plate of red glass, and after a few seconds was hastily transferred into the dark closet, but though the experiment was repeated several times, not the smallest approach towards a red colour was perceived in the light of the phosphorus. The same phosphorus was now exposed to the different coloured rays of the prismatic spectrum, but whatever was the colour of the ray in which it was placed, the same tint of white light was visible in every experiment.

Another piece of phosphorus disposed to shine with a red light was now selected and exposed, first to the common light and afterwards in succession to the different refracted rays as separated by the prism, when it was found that the phosphoric light was much intense when excited by white light, and by far the least when excited by red light; the violet rays excited a degree of red light full ten times as great as the red rays did. Another singular circumstance was, that if the red prismatic rays were thrown upon the phosphorus already made luminous by the violet rays the immediate effect was a remarkable deterioration in the tone of the colour, so that it was scarcely more brilliant than when excited by the red rays. In like manner the red and yellow prismatic rays were found to excite the phosphorescence in a piece of shell disposed to emit blue light, with much more energy than the blue or violet rays themselves.

These singular facts appear scarcely reconcilable to the hypothesis of the phosphorescent light being merely that which has been previously imbibed from the sun, yet on the other

[a] Wilson on Phosphorus, p. 97.

hand they by no means prove that it is properly inherent in the phoſphoric ſubſtance itſelf.

The ſolar phoſphori are not only capable of being excited by the rays of the ſun but by any other light that is ſufficiently powerful, and thoſe phoſphoreſcent ſubſtances which ſhine with the greateſt brilliance by expoſure to the light of day, are, as might naturally be expected, moſt eaſily excited by other luminous bodies. The rays of the moon even when concentrated in a lens appear to be incapable of illuminating even the moſt ſenſible kinds of phoſphori. The light of a bright candle, or the momentary flaſh from the exploſion of a little gunpowder, or from an electrical diſcharge, are ſufficient to render Wilſon's phoſphorus, when well prepared, very viſibly luminous.

It is not very certainly known what is the effect of the different gaſſes on the luminous property of theſe bodies. According to ſome obſervers, a piece of calcareous phoſphorus, when placed in the receiver of an air-pump, becomes rapidly leſs luminous as the air is exhauſted, but according to others the rate at which the light fades is not more rapid than uſual. We have the reſpectable authority of Mr. Canton, for ſtating that his phoſphorus incloſed in a glaſs flaſk, and hermetically ſealed, retains its property of becoming luminous for at leaſt four years, without any apparent decreaſe of activity.

§. 2. *Phoſphori from heat.*

Beſides thoſe ſubſtances that are phoſphoreſcent by expoſure to the rays of the ſun, there are others which give out light when ſimply heated. Theſe materially differ from the former in this circumſtance, that after having been continued at any particular temperature till their luminouſneſs is exhauſted, they are incapable of becoming again luminous, except at a greater heat than that to which they were firſt ſubjected. The range of temperature at which theſe bodies become luminous is not very extenſive, commencing at about 400° Fahr. and terminating at the loweſt viſible red heat. In ſome of theſe phoſphori the light is almoſt momentary, but in others it endures many minutes. The intenſity of the light appears to undergo no ſort of alteration whether the body that emits it is in a Torricellian vacuum, or plunged in any of the natural or artificial gaſſes. The following is a liſt of the ſubſtances exhibiting this property, arranged by Mr. T. Wedgewood according to the brilliancy of their light.[e]

That variety of the blue fluor of Derbyſhire which when ſcraped or ſtruck emits a fetid bituminous odour, is the moſt phoſphoreſcent by heat of all the known ſubſtances; it glows when moderately heated with a pale emerald green light ſufficiently intenſe to be very viſible even in day light, To the ſecond rank belong the common Swineſtone, the common blue fluor, and red felſpar, all theſe as well as the following exhibit a white or reddiſh light. The third claſs includes the diamond, the ruby, carbonated barytes, chalk, colourleſs calcareous ſpar, ſea ſhells, granite, and white fluor. The fourth claſs comprehends white ſand, carbonated magneſia, heavy ſpar, flint, white marble, quartz, porcelain and earthen-ware. The fifth claſs includes moſt of the metals, ſulphat of potaſh, borax, white paper, white linen, ſawduſt and aſbeſtos. Under the ſixth and laſt claſs are comprehended oil, wax, ſpermaceti and butter when boiling or nearly ſo. To exhibit the luminous property of theſe bodies in the greateſt perfection, the harder ones ſhould be reduced to a very coarſe powder and ſprinkled in a dark room on the ſurface of a thick metallic plate heated below redneſs. A very ſtriking exhibition of the phoſphoreſcence of the fetid blue fluor may be made by heating ſome oil in a clear flaſk till it becomes luminous, and then dropping in about a teaſpoonful of pulverized fluor: the inſtant this latter comes in contact with the hot liquid a bright flaſh of green light is given out, which may be renewed for many times by repeatedly ſhaking the veſſel.

Moſt of the above mentioned ſubſtances are phoſphoreſcent alſo by friction, which is aſcribed by Mr. Wedgewood to the heat produced on this occaſion; in ſome inſtances it may, yet as there are certain bodies, ſuch as Tremolite and a particular variety of blende, which give out much light even from the ſcratch of a pin, the luminouſneſs in theſe caſes can hardly have been excited by the reaction of the trifling quantity of heat thus produced. Mr. Davy has alſo obſerved that if fluor be heated till it ceaſed to become luminous, it is ſtill capable of producing light by colliſion.

§. 3. *Spontaneous Phoſphori.*

In this ſection we mean to include certain animal and vegetable ſubſtances which at a particular period of their ſpontaneous decompoſition become luminous. In animal ſubſtances this phoſphoreſcence makes its appearance before the commencement of putrefaction, and

[e] Phil. Tranſ. vol. lxxxii. p. 28

ceases when the latter is compleatly established. The flesh of birds has we believe never exhibited this phenomenon, and that of quadrupeds but rarely. Several species of insects are luminous, as the common glow worm, the fire flies of America, and the fulgora of China; also a kind of crab, (the cancer fulgens) a few shell fish, and some of the marine molluscæ: these however are luminous not merely during the period just mentioned, but also when alive. The flesh of a few fresh water fish especially the carp, and of the tadpole, but not of the frog, becomes luminous before putrefaction. But the flesh of salt water fish more than all other substances is peculiarly rich in phosphorescent matter, and accordingly has been the principal substance on which the following experiments have been made. Of vegetable matters that become luminous the principal is decayed wood; peat also, though very rarely, hase xhibited a similar appearance. The chief observers who have turned their attention to this subject are Boyle, Canton,[f] and Dr. Hulme.[g]

The only laboratory required for these processes is a dark room, and the only preparation of the fish is that they should be gutted and split, and their scales taken off. The herring seems to afford more light than other fish.

The time which sea fish, as fresh as they can commonly be procured in a market, take to become luminous is about 12 hours or less: the phosphorescence is faint and partial at first, but soon spreads over the whole surface, and becomes very bright before any putrefaction comes on; in proportion as this latter state is established the light becomes more faint, but does not entirely disappear in less than four or five days: the luminous matter may be scraped off with a blunt knife, and will continue to shine for a considerable time. But though the emission of light diminishes as putrefaction increases, there appears no necessary connexion between the two processes, for if a piece of herring is put into a brine consisting of 1 part by weight common salt and 8 parts water, it will be found in about 24 hours that the liquor when agitated is slightly luminous, and during the two succeding days its brilliancy will increase; then declining, it will become wholly extinct in three or four days more, and at the end of this period both the flesh and brine will be entirely free from any putrid smell. The sulphats of soda or magnesia employed in the same proportions as common salt will produce similar effects, only the phosphorescence will not continue so long.

The phosphorescence is destroyed by immersion in pure water, in lime-water, carbonated water, and liquid sulphuretted hydrogen, also by fermented liquors, by alcohol, by the mineral and vegetable acids, and by the alkalies, also by *saturated* solutions of those neutral salts which when moderately diluted contribute most eminently to its preservation. Hence if some of the luminous matter be scraped from the surface of the fish, and well shaken in a dilute solution of common salt, Glauber's salt, &c. the whole will appear richly luminous, but by then adding a sufficiency of dry salt to saturate the solution, the light will be extinguished: in this case it is however only latent, for by pouring in pure water enough to reduce the strength of the saline solution, the light reappears as before, a subsequent dose of salt will again extinguish it, and more water will restore its luminousness.

The production of this phosphoric light does not afford any heat ascertainable by the thermometer. By exposure to a freezing temperature the light is rendered latent, but it is wholly destroyed when plunged into boiling water; a considerable warmth however obviously increases its brilliancy.

It appears that this light cannot be produced except by the contact of atmospheric air, yet when once excited it is not increased by being placed in oxygen gas, or impaired by azot. When put into the receiver of an air-pump it becomes faint, and is at length extinguished as the exhaustion of the vessel proceeds; the readmission of air restores its former brightness. Nitrous gas, carbonic acid, hydrogen, and sulphuretted hydrogen totally and instantaneously extinguish it.

The light of dead glow-worms, and of rotten wood follows nearly the same rule with regard to the action of temperature and the gasses as fish light does, but it seems to be little affected by pure water and various saline solutions which have so striking an action on the latter.

PHOSPHURET, PHOSPHURETTED HYDROGEN } See PHOSPHORUS (*Kunckel's.*)

PIERRE PONCE. See PUMICE.

PISOLITE. See LIMESTONE.

PITCH. See TURPENTINE.

PITCH, JEW's. See BITUMEN.

[f] Phil. Trans. lix. p. 446.

[g] Ditto, xc. p. 161. xci. p. 403.

PITCHSTONE. *Pierre de Poix*, Fr. *Pechſtein*, Germ.

The colour of this mineral is very various, being grey and green of various ſhades, alſo honey yellow, liver brown, blood and brick red. The colours are generally pale, and not unfrequently arranged in bands. It occurs in maſs. Internally it is uſually ſhining, with rather a faint greaſy luſtre. Its fracture is imperfectly conchoidal, paſſing into ſplintery, and in proportion as it does ſo its luſtre is fainter, and it approaches to hornſtone. Its fragments are indeterminately angular, ſharp-edged. Sometimes it occurs in ſmooth granular diſtinct concretions. It is uſually tranſlucent only at the edges, the black varieties are opake. It is conſiderably hard, brittle, and eaſily frangible. Sp. gr. 2.3.

It is fuſible before the blow-pipe into a white, ſomewhat porous enamel. According to Wiegleb, the pitchſtone of Meiſſen in Saxony is compoſed of

64.58	Silex
15.41	Alumine
5.	Oxyd of Iron
84.99	
15.01	loſs

Pitchſtone occurs in mountain maſſes, and even conſtitutes entire mountains, and it forms the baſe of a particular kind of porphyry.

It abounds in Saxony, Hungary, Siberia, and other mountainous diſtricts.

It is not unfrequently confounded with hornſtone, and ſemi-opal.

PLASMA. Wern.

The colour of this mineral is green of various ſhades mixed with brown, and the whole arranged in dots, clouds and bands. It occurs in maſs, and in angular and rounded fragments incloſed in talc or ſteatite. It has a feeble greaſy luſtre both internally and externally. Its fracture is conchoidal paſſing to fine ſplintery. Its fragments are indeterminate and ſharp-edged. It is tranſlucent, and in thin pieces ſemitranſparent. Its hardneſs is nearly equal to that of Chalcedony; it is brittle, and eaſily frangible.

Its proper geological ſituation has not as yet been aſcertained; neither has it been ſubmitted to chemical analyſis. It is not uncommon in Italy and the Levant: it occurs near Bojanovitz, in Moravia, imbedded in ſerpentine, and near Toeltſva in Upper Hungary, in rounded pieces with hornſtone. Sometimes it combines with heliotrope and chalcedony, forming agate.

PLATINA. *Le Platine*, Fr. *Der Platin*, Germ. *Aurum album*, Waller.

§ 1. *Ores.*

This metal has hitherto been found only in one ſtate in which according to moſt mineralogiſts and chemiſts it is conſidered as native, though Prouſt is inclined to conſider it as in the ſtate of ſulphuret. From this latter opinion we ſhall take the liberty to diſſent, and ſhall accordingly deſcribe this ſubſtance as

NATIVE PLATINA.

The colour of this mineral is between ſilver white and ſteel grey. It comes to Europe only in the form of flat and more or leſs rounded grains, from the ſize of a pea, which is rare, to that of fine ſand. The ſurface of the grains is moderately ſmooth, and they poſſeſs rather a low degree of metallic luſtre: by friction this brightneſs approaches to that of poliſhed iron: its hardneſs is greater than that of copper: it is conſiderably ductile, and very flexible when in thin plates. Its ſp. gr. is variable, but is ſeldom leſs than 16.5, or greater than 17.2.

It is infuſible before the blow-pipe, and is inſoluble in acids, except the oxymuriatic or nitromuriatic; from its ſolution in this latter it is precipitable by muriat of ammonia, but not by green vitriol.

Nothing is as yet known of the geological ſituation of this ſubſtance except that it accompanies gold. It is found in the Rio del Pinto, and near Choco in the Viceroyalty of Peru, and near Carthagena in New Granada.

A variety of the above in ſmaller grains and of a darker colour, is alſo met with.

Platina was firſt brought into Europe in 1749, by Mr. Chas. Wood, aſſay-maſter of Jamaica, and in the ſucceeding year, ſpecimens were preſented by Dr. Brownrigg, to the Royal Society. Theſe came from Carthagena, from which place alſo were diſperſed through the Spaniſh Weſt Indies, various toys and trinkets conſiſting of this metal alloyed with ſome other, probably ſilver, as the price of the alloy was nearly equal to that of this latter metal.

Mr. Wood and Lewis began the inveſtigation of the properties of this new ſubſtance in the very year in which it was imported: it then employed the abilities of Schaeffer, Marggraaf, Bergman, Macquer, and Beaumé; and more recently of Deliſle, Morveau, Jeanety, Vauquelin and Fourcroy, Deſcotils, Muſſin Puſchkin, Prouſt, Tennant, Chenevix and Wollaſton. Many difficulties however yet remain to be overcome before the chemical hiſtory of this ſubſtance can be compleated.

§ 2. *Analyſis of the Ore.*

As all the platina which comes to Europe has previouſly undergone the proceſs of amalgamation in S. America, it generally happens that a ſmall variable quantity of mercury remains in it, ſometimes in very ſmall diſtinct globules, but more generally combined with gold into an amalgam. The eaſieſt way of ſeparating the mercury is to drive it off by heat, either in an open ladle or in an earthen retort, according as this ſubſtance is or is not to be retained. When the mercury is thus got rid of, the remaining platina has generally a much yellower caſt than before, on account of the particles of gold diſperſed through it having now acquired their characteriſtic colour. The ore is now to be ſpread thin on a ſmooth table, and by the dextrous application of a common pair of bellows, the lighter particles may be ſeparated with very conſiderable accuracy from the heavier ones. The former conſiſt of very minute cryſtals and fragments of quartz, and of two kinds of iron ore in fragments and in ſmall octohedrons: of which ſome are compleatly attractible by the magnet, (being the magnetic iron ſand) while the others are not in the leaſt ſo, and give out when roaſted, a ſlight ſulphureous odour.

The heavier particles are now to be treated with a ſmall quantity of a ſomewhat diluted nitromuriatic acid, by which the whole of the gold will be taken up, with ſome iron and a very ſmall proportion of platina and the other ingredients. From this ſolution the gold may be thrown down by means of green ſulphat of iron, and purified by ſubſequent fuſion with a mixture of nitre and borax. The proportion of gold contained in crude platina is generally pretty conſiderable, ſo as to render it well worth the labour of the chemiſt to ſeparate it if he is poſſeſſed of a conſiderable quantity. From one parcel conſiſting of 100 ounces, Prouſt[a] obtained 7 oz. of gold, and from another like quantity he procured no leſs than 13 oz. The whiteſt platina is the richeſt in gold, the black varieties containing little or none of it.

After the ſeparation of the gold, the platina is to be digeſted in nitromuriatic acid, by which it will be diſſolved, with the exception of a black matter, which was at firſt taken for plumbago, but which, from Mr. Tennant's recent analyſis appears to be a compound of two new metallic bodies, that have obtained the names of oſmium and iridium. By the addition of muriat of ammonia to the nitro-muriatic ſolution, the greateſt part of the platina is thrown down in the form of a yellow powder, which is a nearly inſoluble ammoniaco-muriat of platina. The ſolution is now to be treated with zinc, by which all its metallic contents except the iron, will be precipitated, and this precipitate when waſhed is to be digeſted in very dilute nitric acid: by this menſtruum the copper and lead uſually contained in crude platina will be got rid of, and the remainder is to be diſſolved in nitro-muriatic acid. To this latter ſolution common ſalt is to be added, and the whole evaporated to dryneſs. This reſidual ſalt contains the ſoda-muriats of platina, palladium, and rhodium, of which the latter alone is inſoluble in alcohol, and may therefore be ſeparated from the former by means of this fluid. The alcoholic ſolution now contains platina and palladium, from which nearly the whole of the former is to be ſeparated by ſal ammoniac. The ſolution being now diluted, the addition of pruſſiat of potaſh will throw down the palladium in the form of a deep orange precipitate, and from the remaining liquor when concentrated, the platina may be precipitated by muriat of ammonia.

§ 3. *Methods of working Platina.*

The great infuſibility of platina, added to the ſtrong reſiſtance which it oppoſes to common menſtrua, long excited the attention of chemiſts and artiſts, and has given birth to various ingenious proceſſes for condenſing this refractory metal into malleable maſſes, and forming of it crucibles and other inſtruments of material ſervice to the accuracy and ſimplicity of chemical analyſis. If the largeſt and whiteſt grains are carefully ſelected from a parcel of crude platina, it will be found that theſe are conſiderably malleable even when cold, and ſtill more ſo when hot: alſo if two grains are laid in contact with each other and then brought to the higheſt poſſible white heat, they may be made to adhere more or leſs perfectly by a ſtroke with a hammer, and in this way, by great patience and great dexterity, it may be practicable to form a few grains into a maſs. This however is by much too imperfect and tedious a method to be employed with any practical advantage.

It was early diſcovered that arſenic combined very readily with platina, forming an alloy of eaſy fuſibility, and from the volatility of the former of theſe metals, eſpecially when in contact with charcoal, it was expected that by

[a] Ann. Chim. xxxviii, p. 148.

proper management nearly the whole of it might be driven off, leaving the platina behind in a maſs, and poſſeſſed of its characteriſtic properties. Willis, Marggraaf, Achard and others ſucceeded to a certain degree, and faſhioned of this alloy crucibles and other chemical utenſils, leſs fuſible than ſilver, and capable of reſiſting many of the common menſtrua. M. Jeanety of Paris, a working ſilverſmith, then turned his attention to the ſame object, and after long practice and many failures, diſcovered by far the beſt method of preparing and working this alloy. The proceſs of this artiſt as reported by Berthollet and Pelletier, is the following:[b]

Having firſt ground the crude platina in water, and waſhed it over in order to ſeparate the earthy matters with which it is mixed; take three half pounds of the metal, three pounds of white arſenic, and one pound of pearlaſh: mix the whole well together, and then place in a furnace of any convenient conſtruction, a crucible capable of holding 20 lbs. of the above mixture. As ſoon as the crucible is thoroughly red hot, pour in one third of the mixture, and keep ſtirring it with a rod of platina till it comes into a ſtate of quiet fuſion; Then add another third, carefully ſtirring it as before, and after a while add the remaining third, and give the whole a good heat, ſo as to render it very fluid. Then withdraw the crucible, and after it has cooled, gradually break it up: there will be found a well formed metallic button, covered by blackiſh brown ſcoriæ, which acts pretty powerfully on the magnetic needle. This button being broken to pieces, (which is readily done on account of its great brittleneſs,) is to be again fuſed with white arſenic and pearlaſh as before, and the metallic maſs reſulting from this ſecond fuſion is generally incapable of acting on the magnetic needle: if however, this ſhould not be the caſe, a third fuſion with arſenic and alkali muſt be had recourſe to.

The firſt ſtep of the proceſs being thus finiſhed, a flat bottomed cylindrical crucible, about 3½ inches in diameter is to be made thoroughly hot in a furnace, and is then to be charged with three half pounds of the arſenicated platina mixed with an equal weight of white arſenic, and half a pound of potaſh: when theſe are well mingled and entirely fluid, the crucible is to be removed from the fire, and placed to cool in a horizontal poſition, in order that the cake of metal may be of an uniform thickneſs. The crucible when cold is to be carefully broken, and having removed the ſcoriæ, there will be obtained a cake of metal well formed and ſonorous, weighing about three ounces more than the arſenicated platina employed, and now quite ſaturated with arſenic: there is no danger of incorporating too much of this latter ingredient, it being conſtantly obſerved that the compleatneſs and rapidity of the ſubſequent purification is exactly in proportion to the quantity of arſenic which it has previouſly been made to imbibe.

The metallic maſs thus procured is to be placed in a muffle, and the heat is to be gradually increaſed till the arſenic begins to evaporate; the temperature muſt then be kept up as nearly as poſſible the ſame for ſix hours, obſerving eſpecially not to increaſe it leſt the cake melt. At the end of this period the cake will have become conſiderably porous, and is now to be withdrawn and extinguiſhed in common oil; it is then to be returned to the muffle, by which a further quantity of arſenic will be evaporated, and this alternate application of oil and heating, is to be continued till no more arſenic makes its appearance. The fuſibility of the maſs diminiſhes as the arſenic is got rid of, ſo that a much higher temperature may be employed in the latter than in the former part of this proceſs. Having carefully burnt off at a high heat all the charcoal produced by the decompoſition of the oil, the ſpungy cake of metal is to be digeſted in nitrous acid, and then edulcorated by repeated boiling in water. Three or more of the cakes are then to be put into a cylindrical crucible, and heated to the higheſt poſſible degree in a powerful furnace: while they are thus rendered ſoft, an iron peſtle let down upon them will make them cohere: they are then to be withdrawn from the crucible, heated to the utmoſt in a ſmith's fire, and carefully forged like iron on the anvil into compact bars.

The advantage of this proceſs of M. Jeanety is its cheapneſs, not requiring the platina to be previouſly diſſolved in nitro-muriatic acid; but on the other hand, the metal, though approaching a ſtate of purity, is by no means abſolutely pure: it contains a ſmall quantity of arſenic and iron, together with, probably the whole of the lead and copper that may have been caſually mingled with the ore, as well as the palladium, oſmium, iridium and rhodium, and in conſequence of this mixture is by no means capable of ſuſtaining the action of alkalies and a high heat with ſo little injury as when more accurately purified.

[b] An. Chim. xiv. p. 29.

The next method which we shall mention of purifying this metal was discovered by Count Moussin Pouschkin.[c] It is effected in the following manner. Dissolve the crude platina in nitro-muriatic acid, and throw down the platina by muriat of ammonia, and wash the precipitate in a little cold water. Then heat the yellow powder in a crucible till it is decomposed, and the platina becomes spungy and returns to the metallic state: now wash the mass with hot water, and boil it in very dilute muriatic acid, to dissolve out any iron that may be casually mixed with it; then edulcorate and dry the residue. Of this residue take a few drams with twice its weight of pure mercury, and triturate the mixture in a stone mortar till an amalgam is produced, which may be effected without difficulty, after which by the alternate addition of mercury and platina several pounds weight of ingredients may be amalgamated in the course of a few hours. This amalgam when first made is soft, but in an hour or a little more acquires a considerable hardness; while yet soft therefore it should be closely rammed into a tube of wood of convenient size, and after it has become hard, the tube with its contents may be placed in a muffle, and by the time that the wooden covering is consumed, a great part of the mercury will be volatilized, so as to prevent all risk of the bar of platina breaking when deprived of the support of its wooden case. The metal is now to be cautiously heated till all the mercury is driven off, after which it is to be forged in the usual way at the highest possible heat.

A still more simple and equally effectual manner of working this metal has been published by Mr. Knight.[d] The platina being dissolved in nitro-muriatic acid and precipitated by muriat of ammonia, the yellow powder hence resulting after being edulcorated by washing in cold water is to be thus managed. "A strong hollow inverted cone of crucible earth being procured, with a corresponding stopper to fit it, made of the same materials, the point of the latter is cut off about three fourths of the distance from the point to the base. The platina in the state of a light yellow powder is pressed tight into the cone, and a cover being fixed slightly on, it is placed in an air furnace and the fire raised gradually to a strong white heat. In the mean time the conical stopper fixed in a pair of iron tongs suitable for the purpose, is brought to a red or a bright red heat. The cover being then removed from the cone, the tongs with the heated stopper is introduced through a hole in the cover of the furnace, and pressed at first gently on the platina, at this time in a state nearly as soft as dough, till it at length acquires a more solid consistence. It is then repeatedly struck with the stopper as forcibly as the nature of the materials will admit, till it appears to receive no further impression. The cone is then removed from the furnace, and being struck lightly with a hammer the platina falls out in a metallic button, from which state it may be drawn by repeatedly heating and gently hammering, into a bar."

The last method that we shall notice and one that has been attended with compleat success, was invented by Mr. T. Cock, through whose liberality we are enabled to communicate it to our readers.[e]

The platina being dissolved in nitro-muriatic acid, the liquor is to be filtered through clean white sand, in order to separate the black powder which floats among it. The clear solution being then decomposed by sal-ammoniac the yellow precipitate is to be collected, moderately well washed in warm water and dried. It is then to be distributed into saucers which are placed in a small oven constructed for the purpose, where they are exposed for a short time to a low red heat in order to bring the platina to the metallic state, and to drive off by sublimation the greater part of the muriated ammonia. When withdrawn it is a spungy mass of a grey colour. About half an ounce of the platina in this state is to be put into a strong iron mould about $2\frac{1}{2}$ inches long by $1\frac{1}{4}$ wide, and is to be compressed as forcibly as possible by striking with a mallet upon a wooden pestle cut so as accurately to fit the mould; another half ounce is then added and treated in the same manner, and so on till six ounces have been forced into the mould: a loose iron cover just capable of sliding down the mould is then laid upon the platina, and by means of a strong screw press, almost every particle of air is forced out from among the platina. This is a part of the process that requires especial care, for if any material quantity of air is left in the mass, the bar into which it is formed is very apt in the subsequent operations to scale and be full of flaws. The pressure being duly made, the mould is to be taken to pieces, and the platina will be found in the form of a dense compact parallelopiped. It is now to be placed in a charcoal forge fire and heated to the most

[c] Nich. Journ. ix.

[d] Tilloch Phil. Mag. vi. p. 3.

[e] Original communication.

intenfe white heat in order compleatly to drive off the remaining ammoniacal muriat; this being done it is to be quickly placed on a clear bright anvil and gently hammered in every direction by a clean hammer. This is to be repeated feveral times, at the end of which the mafs will be perfectly compact, and fit to be laminated or wrought in any other manner that the artift chufes. It is to be obferved that while the platina is heating it muft lie loofe in the fire, for if it were held by the tongs they would infallibly become welded to the platina, and thus greatly damage it. By the time that the platina is thus drawn down to a compact bar it will be covered by a fomewhat reddifh femivitreous cruft proceeding chiefly from particles of the afhes melted down upon it and extended over its furface by the hammer. To remove this, the bar being made red hot is to be fprinkled over with pulverized glafs of borax, and then kept for a few minutes at a white heat; when moderately cool it is to be plunged into dilute muriatic acid by which the borax and other vitreous matter will be diffolved, leaving the platina with a perfectly clean white furface.

§. 4. *Phyfical and Chemical Properties of Platina.*

The colour of this metal is between tin-white and iron-grey. Its ductility and malleability are both very confiderable as it may be drawn into fine wire, and be beaten into leaves as thin as tin-foil. It poffeffes a confiderable elafticity, and in hardnefs is not much inferior to iron; hence it may be made to receive a high polifh. It is fufible by galvanifm, and by the concentrated rays of the fun, but is fcarcely to be melted by the most powerful furnace. At a full white heat it poffeffes the property of welding like iron, and two pieces may thus be made to unite with perfect accuracy. It is not oxydable by the higheft heat, or the combined influence of the air and moifture; hence it is entitled to rank among the noble or perfect metals.

The only acid menftrua by which it is capable of being diffolved are the oxymuriatic and nitromuriatic acids, the latter being moft commonly employed for this purpofe. Refpecting the compofition of this acid and the proportion of platina that it is capable of diffolving there is very little agreement among chemifts. The common method is to prepare the acid by mixing together equal parts of ftrong aquafortis and fuming muriatic acid, and of this menftruum from 16 to 24 parts are required for the folution of one of platina. By this mode of proceeding however there is a moft unneceffary wafte of nitric acid, and the folution always contains an excefs of acid. A much more fatisfactory refult has been obtained by Prouft,[f] and which appears to be the more worthy of credit as it is deduced from feveral experiments on a large fcale. The acids employed by this able chemift were common ftrong aquafortis of 35° Beaumé, and muriatic acid of 15°. A nitro-muriatic acid compofed of thefe in the proportion of 4 oz. by weight of the former, and 12 oz. of the latter, being digefted on 6 oz. of platina was found to take up 17¾ drachms; the folution being then concentrated by gentle diftillation, the acid liquor that came over, weighing 10 oz. 1 drachm, after being ftrengthened by 4 oz. of muriatic acid was found to be capable of taking up about 8½ drachms more of platina. Hence it appears that 16 oz. of muriatic acid, and 4 oz. of nitric are adequate by proper management to the folution of 26¼ drachms (3 oz. 2¼ dr.) of platina. In general a confiderable quantity of acid is loft by the imprudent application of heat in this procefs, fo that the beft mode of performing this operation, efpecially when any confiderable quantity is employed, is to pour the whole of the muriatic acid on the platina in a retort with about ¼ of the nitric acid and allow them to act on each other in a moderate warmth till all effervefcence has ceafed; then to add another portion of nitric acid, and fo on till the whole has been made ufe of; then to proceed to diftillation, and after ftrengthening the product with frefh muriatic acid to digeft it on a frefh portion of platina; which being compleated both the folutions may be added together. If crude or imperfectly purified platina is employed, a portion of black matter will remain undiffolved, and the colour of the folution will approach more or less to a deep orange brown inftead of being orange yellow, the colour of pure muriat of platina.

Muriat of ammonia decompofes this folution and throws down a triple falt, the ammoniaco-muriat of platina, which if pure is yellow, but of a brick red if combined with the other metallic oxyds. This falt is fparingly foluble in boiling water; one ounce of it being boiled with repeated portions of pure water requires between 8 and 9 lbs. for its compleat folution.[g] If the falt is of a brick red colour the folution is yellowifh red verging on green, and depofits by ftanding a little black matter, and changes to

[f] An. Chim. xxxviii. p. 232.

[g] Mouffin Poufchkin, An. Chim. xxiv. p. 205

a bright orange colour, from which by repeated slow evaporation and crystallization may be obtained small octohedral crystals of a high topaz colour. The yellow ammoniacal muriat when decomposed by heat leaves behind about 42.5 per-cent. of platina which is rapidly soluble in nitro-muriatic acid; the red salt on the other hand affords about 44 per cent. of metal, which is with difficulty acted on by aqua regia, and a small portion in the form of a black powder absolutely refuses to dissolve. That this red salt contains some other metal besides platina is further obvious from this circumstance, that if the residue after its decomposition by heat be placed in a tube heated red hot, and exposed to a stream of oxygen gas, a blue metallic oxyd will be volatilized, which appears to be the same with the iridium of Mr. Tennant. Ammoniaco-muriat of platina is also decomposable by oxymuriatic or nitro muriatic acids which destroy the ammonia and reduce the solution to simple muriat. It is also in part at least decomposable by the caustic fixed alkalies and lime-water.

Potash is also capable of uniting with muriat of platina forming with it a triple salt, the general properties of which are analogous to those of the preceeding. Soda combines in like manner with muriat of platina into a triple salt. The most convenient way of preparing it is to mix with the muriat of platina a solution of common salt, from which by evaporation and cooling may be obtained long prisms or triangular tables of the salt in question. The colour of this salt if the platina was pure is a bright yellow. It is very soluble not only in water but in alcohol, in which it differs from the two preceding salts; it is decomposable by muriat of ammonia, which throws down the ammoniaco-muriat of platina; it is also decomposable by the fixed alkalies either pure or caustic, but if they are added to excess the oxyd of platina is again dissolved by them. When heated before the blow-pipe on charcoal this salt boils, and is decomposed, the platina being reduced to the metallic state.[b]

The sulphuric, nitric, and oxalic acids, though they have no effect on the pure metal, dissolve its oxyd and form with it salts that have hitherto been very little examined.

The salts of platina are not decomposed either by gallic acid, infusion of galls, or prussiat of potash. Sulphuretted hydrogen throws down a brown precipitate consisting for the most part of metallic platina.

The action of the caustic fixed alkalies at a high heat on platina is considerable, the metal being corroded and partly dissolved, a circumstance which considerably diminishes the use of crucibles formed of this substance in the analysis of the more refractory stony minerals. Nitre produces a similar effect. Mr. Tennant found[i] that by heating nitre with some thin pieces of platina in a cup of the same metal, the cup was much corroded and the thin pieces were entirely destroyed. By dissolving the saline mass in water the greater part of the platina was precipitated in the form of a brown powder. This powder was entirely soluble in muriatic acid, and consisted of oxyd of platina combined with potash. Part of the platina was retained by the alkaline solution to which it communicated a yellowish brown colour. On the addition of an acid an insoluble triple salt was produced consisting of oxyd of platina, potash, and the acid employed.

Platina combines by fusion with many of the metals. With gold it forms an alloy that has been already described. With silver it composes a moderately easily fusible alloy, of a silvery white colour, considerably malleable, and capable of a high polish; but when heated red it becomes of an iron-black colour, blisters and throws off scales so as to render it incapable of being wrought. A remarkable property of this alloy is that it is very apt on consolidating from fusion to become entirely covered with a sort of imperfect crystallization, thus becoming as rough as the coarsest file. Lead combines without difficulty with platina at a full red heat, forming a somewhat malleable alloy of easy fusibility; by cupellation a considerable portion of the lead is worked off, but the remaining alloy is too fusible and too easily acted on by menstrua to enable it to supply the place of pure platina as a material for crucibles, &c.

The spungy metallic mass remaining after the decomposition by heat of the ammoniaco-muriat of platina enters readily into combination with mercury, as we have already mentioned, forming an amalgam. If instead of the platina, the triple salt itself is triturated in an earthen ware mortar with an equal weight of mercury, the salt in a short time, according to Moussin Pouschkin, loses its orange yellow colour, and passes first to brown and then to greenish brown; a second portion of mercury brings the whole to the state of a grey powder, a third causes a commencement of amalgama-

[b] Descotils in An. Ch. xlviii. p. 165.

[i] Phil. Transf 1797. p. 221.

tion, and by the time the ſixth is added the amalgam is compleated. If the amount of mercury is even nine times as great as that of the ſalt the amalgam will ſtill be very ſtiff and tenacious, and as brilliant as the beſt amalgam of tin. It is a remarkable property however of this mixture, that if it is triturated for a few minutes with water, or rubbed in the palm of the hand, it is rapidly converted into a grey powder which is oxyd of mercury, with ſeveral brilliant particles of platina diſperſed through it, and a little running mercury uſually alſo makes its appearance. This grey powder by ſublimation in a retort, furniſhes metallic mercury, and a little calomel.[k]

Platina is not capable of combining with ſulphur, but unites readily with phoſphorus, from which it cannot be ſeparated by mere heat.

§. 4. *Oſmium, Iridium, Rhodium and Palladium.*

Of the above four new metals which have recently been diſcovered in crude platina ſo few particulars have as yet been obſerved that we have thought it moſt adviſable to treat of them in an appendix to the article platina.

It has been already mentioned that in diſſolving crude platina in nitro-muriatic acid, a black powder is ſeparated which has been ſuppoſed by ſome chemiſts to be oxyd of iron, by others has been conſidered as plumbago, but has been lately diſcovered by Mr. Tennant to contain two new metals. If in treating the crude platina a large proportion of ſtrong acid at a boiling temperature is made uſe of, nearly the whole of the black powder is diſſolved, and the platina thrown down from the ſolution by muriated ammonia inſtead of being yellow is of a brick-red. But if a weaker acid at a much lower temperature is employed, the ſolution is much leſs coloured and nearly 3 *per cent.* of this black powder remains, which may be readily ſeparated by filtration and waſhing.

[l]This black matter is partly in ſcales and partly pulverulent; it leaves black traces on paper as plumbago does, but differs remarkably from this latter in its sp. gr. which is $=10.7$. It unites readily with lead, but the compound even if containing no more than $\frac{1}{11}$ of this black matter, poſſeſſes very little fluidity when melted. Nitrous acid diſſolves out the lead, leaving the other ingredient nearly in the ſame ſtate as at firſt. With biſmuth, zinc, and tin, the effects are nearly ſimilar; but with copper at a very high heat it contracts a more intimate union, for by digeſting the compound in nitro-muriatic acid ſome of the powder was taken up together with the copper forming a very dark-coloured ſolution.

With ſilver and gold it unites eaſily and intimately, and is incapable of being ſeparated from either by cupellation, or from gold even by quartation: the alloys retain conſiderable ductility, and the colour of that with gold is not materially different from pure gold.

If this black powder be mixed with a large proportion of cauſtic ſoda, and kept for ſome time at a red heat, in a ſilver crucible, the maſs acquires a browniſh-yellow colour. On the addition of water a peculiarly pungent odour is extricated and the alkali with part of the yellow powder is diſſolved. This alkaline ſolution contains the oxyds of OSMIUM and iridium, the former of which may be obtained pure by ſlightly ſuperſaturating the ſolution with ſulphuric acid and proceeding to diſtillation, the metallic oxyd being very volatile, riſing with the water and remaining in ſolution with this fluid in the receiver; as however a little ſulphuric acid is liable alſo to come over, a ſecond very gentle diſtillation is required to procure the oxyd quite pure. The ſolution thus obtained is as colourleſs as water; it has a ſweetiſh taſte and a ſtrong peculiar odour; it does not change vegetable blues to red. Oxyd of oſmium may be obtained in a much more concentrated ſtate by diſtilling the original black powder with nitre. When the materials approach to a red heat there ſublimes into the neck of the retort a fluid apparently oily, but which on cooling concretes into a ſolid colourleſs ſemi-tranſparent maſs. In this concentrated ſtate it ſtains the ſkin of a permanent dark colour. It is ſoluble in water, and then exhibits the properties of the above-mentioned ſolution. The ſalts of platina or gold when dropped into it produce no apparent chemical change, but with nitrat of lead it gives a yellowiſh brown precipitate, with nitrat of mercury a white one, and with muriat of tin a brown one. An infuſion of galls produces a purple colour which ſoon changes into a deep vivid blue. With pure ammonia or carbonat of ſoda it acquires a light yellow colour, and with lime a ſimilar colour but of a brighter tinge; this latter ſolution affords with infuſion of galls a deep red precipitate which becomes blue by acids. Pure magneſia or carbonat of lime produce no effect on this oxyd. On the addition of alcohol, the

[k] An. Ch. xxiv. p. 209.

[l] Tennant in Phil. Tranſ 1804, p. 412.

whole ſolution acquires a dark colour, and after ſome time the oſmium is depoſited (probably in the metallic ſtate) in the form of black films. A ſimilar effect, but much more ſpeedily, is produced by ether. The watery ſolution of this oxyd is decompoſed by all the metals except gold and platina, a black or dark grey precipitate being thrown down conſiſting of the mixed oxyds of oſmium and of the precipitant. A little mercury ſhaken with the above ſolution ſpeedily deprives it of all odour, and combines with the oſmium into an amalgam; this amalgam being expoſed to heat in cloſe veſſels, the mercury is volatilized and a dark grey or blue powder remains behind, which is the pure metal. When heated with acceſs of air it evaporates with the uſual odour; but if the air is carefully excluded it ſeems neither volatile nor fuſible even at a full white heat and in contact with charcoal. But when heated with copper or gold it melts with them forming uniform malleable alloys.

The pure metal after having been ſtrongly heated is not affected by nitro-muriatic acid, but when heated in a ſilver crucible with cauſtic alkali it combines readily with it, and gives a yellow ſolution, from which acids expel the oxyd of oſmium with its uſual properties.

We have already mentioned that the black powder obtained from crude platina, contains both oſmium and iridium. The method of ſeparating the former has been juſt now treated of, we ſhall now therefore proceed to ſhow how to procure the latter. Vauquelin's[m] method is to fuſe the black powder with four times its weight of cauſtic potaſh, which gives a green ſaline maſs: by digeſtion with water a green ſolution is obtained, and ſome green powder remains undiſſolved. The alkaline ſolution is to be ſaturated with muriatic acid, by which a green precipitate will be obtained, and this, together with the green powder, is to be digeſted in ſtrong muriatic acid. The deep green muriatic ſolution thus prepared, contains the oxyds of iridium, iron, and oſmium, and when heated to ebullition, its colour changes to a bright red. It is now to be gently evaporated to dryneſs, and the reſidue being treated with alcohol, the muriat of iron will be diſſolved, leaving behind a red powder entirely free from this metal. This red powder being calcined at a red heat in an open crucible, there firſt ariſes muriatic acid, and then a vapour which tinges the flame of the coals of a fine blue, and which doubtleſs is the oxyd of oſmium; a black powder remains behind, which, when mixed with borax and expoſed to a very high heat, is reduced into a half fuſed granular metal, of a white colour, and very brittle, which is pure Iridium. The metal in this ſtate is ſoluble only in nitro-muriatic acid, and that in ſmall quantity, and with conſiderable difficulty. The colour of the ſolution is a very deep red, which is deſtroyed by green ſulphat of iron. It affords no precipitate with muriat of ammonia; with pruſſiat of potaſh it gives a brown precipitate, which becomes green by the action of the air. When added to a ſolution of pure platina, it cauſes the precipitate of this latter by ſal-ammoniac, to be of a deep-red colour, inſtead of the light yellow which it affords when pure.

Mr. Tennant ſeparated the iridium from the other metals with which it is mixed, in the following manner. He treated the black powder alternately with cauſtic ſoda, and muriatic acid: the acid ſolution, conſiſting chiefly of muriat of iridium, was of a dark-blue colour, which afterwards became of a duſky olive-green, and finally, by continuing the heat, of a deep-red colour. By ſlow evaporation of the ſolution only an imperfectly cryſtallized ſaline maſs was obtained, but this being dried on blotting paper and again diſſolved in water, afforded on evaporation diſtinct octohedral cryſtals. Theſe cryſtals are the pure muriat of iridium, and when diſſolved in water give a deep orange-red coloured ſolution. With an infuſion of galls no precipitate is formed, but the colour of the ſolution is inſtantly and almoſt entirely taken away. Muriat of tin, carbonat of ſoda, and pruſſiat of potaſh, produce nearly the ſame effect. Ammonia precipitates the oxyd, but if in exceſs, rediſſolves a portion, forming a purple liquor. The pure fixed alkalies throw down the oxyd of a brown colour, but retain a part in ſolution, and thus acquire a yellow colour. Muriat of iridium is decompoſed by all the metals except gold and platina, a black precipitate being thrown down, which doubtleſs is metallic iridium. It may alſo be obtained pure by heating the octohedral muriat, which expells the oxygen and acid; the metal remains of a white colour, and nearly infuſible. It does not combine either with ſulphur or arſenic; it unites with lead, but is readily ſeparable by cupellation. With copper it forms a very malleable alloy, as it alſo does with ſilver. Gold alloyed even with a conſiderable quantity of iridium, is perfectly malleable, and nearly of the ſame colour with pure gold: it is not ſepa-

[m] An. de Ch. xlviii. p. 178.

rable either by cupellation or quartation: by digestion in nitro-muriatic acid the gold is dissolved, and the iridium remains behind in the form of a black powder.

All that is hitherto known of the newly-discovered metal called RHODIUM, has been communicated to the public by Dr. Wollaston.[n] It is thus procured. Some crude platina being digested in moderately dilute nitro-muriatic acid, a brownish-red solution is obtained: from this the platina is to be separated for the most part by muriat of ammonia, and the residual liquor is to be heated with zinc; by this treatment a black powder will be obtained, and the supernatant fluid will consist of the muriats of zinc and iron. This black powder by digestion in very dilute nitric acid, will be freed from the copper and lead which it usually contains, and the residue is to be digested in dilute nitro-muriatic acid, till every thing soluble is taken up. To this solution a little common salt is to be added, and the whole evaporated to dryness, after which, by repeatedly washing with warm alcohol, the soda-muriats of platina and palladium will be dissolved, leaving behind a pure soda-muriat of rhodium.

This salt is readily soluble in hot water, and deposits on cooling rhomboidal crystals of a bright rose colour. Sal ammoniac occasions no turbidness in the solution, but if a few drops of muriat of platina are added to the mixture, an immediate yellow precipitate is thrown down. Neither prussiat of potash, nor hydrosulphuret of ammonia, nor the carbonated alkalies, produce any precipitate; but the pure alkalies throw down a yellow oxyd resoluble either in alkalies or acids.

The muriat of this metal is an uncrystallizable salt of a rose colour, and soluble in alcohol: with nitre or the muriats of ammonia or soda, are formed crystallizable triple salts insoluble in alcohol.

Nitrat of rhodium is also uncrystallizable. It appears not to be decomposable by silver, but is so by copper, mercury, and most of the other metals.

The soda muriat of this metal affords a black powder by digestion with zinc, which when heated with borax, acquires a white metallic lustre, but is infusible by any heat that has hitherto been applied. It is however fusible either with arsenic or sulphur, and may be again separated from these substances by heat, but it does not acquire by this treatment any degree of malleability. It combines with most metals, and with silver and gold forms very malleable alloys, which are unaltered by a high heat, but become encrusted with a black oxyd when slowly cooled. An alloy of 6 parts of gold and 1 of rhodium, differs but little in colour from fine gold, but is much more difficultly fusible. The sp. gr. of rhodium appears to be somewhat more than 11.

In the preceding account of rhodium, we have mentioned the method of separating the soda-muriat of this metal from the soda-muriats of platina and palladium, by means of warm alcohol. This being done, the alcoholic solution is to be mixed with a solution of muriated ammonia, by which the greater part of the platina will be precipitated: the supernatant liquor being then poured off and diluted, there is to be added prussiat of potash, as long as any precipitate is produced. There is thus obtained a deep orange coloured sediment, which changes by degrees to a dirty bottle green This when dried is to be heated with a little sulphur, and fused into a button, after which it is to be strongly heated with glass of borax, till on cooling it acquires a bright metallic surface; being now separated from the borax and exposed to the flame of the blowpipe, the sulphur is volatilized, and there remains behind a spungy malleable metallic mass, which is pure PALLADIUM.[o]

This metal in its colour greatly resembles platina; when rolled into a thin lamina it is very flexible, but not very elastic. Its specific gravity varies from 10.9 to 11.9. Its hardness is somewhat superior to that of bar iron; its fracture is fibrous, and it is very malleable. When heated below redness it acquires a superficial blue tinge, but neither at this nor at a higher temperature, is there the least appearance of oxydation. At a full white heat it enters into fusion. It readily combines with sulphur, and the compound is brittle, of a whiter colour than the pure metal, and fusible at nearly the same degree as zinc.

Palladium unites with gold; and the alloy, when equal parts of the ingredients are used, is of a grey colour, equal in hardness to wrought iron, slightly malleable, and of a coarse-grained fracture. Sp. gr. 11.07.

Equal parts of platina and palladium form an alloy resembling the former ingredient in colour and hardness, but in fusibility resembling palladium. Sp. gr. 15.1.

Equal parts of palladium and silver produce an alloy somewhat harder than silver, and in colour resembling platina, only whiter. Sp. gr. 11.2.

With an equal weight of copper this metal

[n] Phil. Trans. 1804. p. 419.

[o] Chenevix in Phil. Trans. 1803. p. 290. Wollaston in ditto, 1804. p. 426.

forms a yellowiſh alloy, harder than wrought iron, and ſomewhat brittle. Sp. gr. 10.3.

With an equal weight of tin, a greyiſh alloy is produced, inferior in hardneſs to wrought iron, and extremely brittle: its texture is compact and fine-grained. Sp. gr. 8.1.

With an equal weight of biſmuth it gives a grey alloy, very brittle, and nearly as hard as ſteel. Sp. gr. 12.5.

Arſenic increaſes the fuſibility of this metal, and renders it very brittle.

Sulphuric acid, when boiled upon palladium, diſſolves a ſmall portion, and acquires a bright red colour. Muriatic acid alſo by long ebullition takes up a portion, and becomes of a red colour. Nitric acid, eſpecially when yellow and fuming, acts with vigour on this metal, converting it firſt into a red oxyd, and then diſſolving it. Nitro-muriatic acid is however the beſt ſolvent of palladium, and forms with it a beautiful red ſolution. From theſe acid ſolutions the alkalies and earths throw down precipitates, moſtly of a bright orange colour, which are partly rediſſolved by the alkalies if added in exceſs: the ſupernatant liquor of the precipitate by ammonia, is often of a greeniſh-blue. The ſulphats, nitrats, and muriats of potaſh or ammonia, produce an orange precipitate, as they do with the ſalts of platina. All the metals, except gold, platina, and ſilver, occaſion a copious precipitate of palladium in the metallic ſtate. Recent muriat of tin produces a dark orange or brown precipitate in the neutralized ſalts of palladium; but if added to exceſs, the liquor remains tranſparent and of a beautiful emerald green. Green ſulphat of iron throws down the palladium in the metallic ſtate. With pruſſiat of potaſh it forms an olive-green precipitate, and with ſulphuretted hydrogen a dark-brown one.

Theſe characters are ſufficient to diſtinguiſh palladium from platina, and every other of the known metals. It was ſuſpected by Mr. Chenevix to be a compound of mercury and platina, but the experiments of this gentleman having totally failed in the hands of other chemiſts, it muſt be conſidered, for the preſent at leaſt, as a diſtinct metallic ſpecies.

PLUMBAGO. See Coal. Sp. gr. 9.

PNEUMATIC APPARATUS. See Appendix.

POLIERSCHIEFER. Poliſhing ſtate.

Its colour is yellowiſh-grey, approaching to cream-colour; it is always ſtriped.

It occurs in maſs: it is dull internally. Its longitudinal fracture is ſlaty; the croſs fracture is earthy. Its fragments are tabular. It is ſoft; adheres to the tongue; is fine but meagre to the touch; and is ſometimes ſo light as to float on water.

It occurs in the vicinity of pſeudo-volcanoes in Bohemia.

PONDEROUS EARTH See Barytes.

PORCELAIN. See Pottery.

PORCELAIN, Reaumur's. See Glass.

PORPHYRY.

A large and important claſs of primitive rocks is diſtinguiſhed by modern mineralogiſts by the name of porphyry. It is eſſential to porphyry to conſiſt for the moſt part of a compact paſte, in which are implanted grains or ſolitary cryſtals of felſpar, of the ſame formation as the principal part of the rock. There are however ſeveral ſpecies of rock agreeing with this definition, which are however arranged among the primitive or ſecondary traps, and will therefore be treated of hereafter.

There are five ſpecies of rocks belonging to the proper porphyritic formation, namely,

1. Hornſtone porphyry. The hornſtone which ſerves as the baſe of this ſubſtance is generally red or green, with a conchoidal or ſplintery fracture; and it incloſes cryſtals of quartz and felſpar.

2. Felſpar porphyry. The baſe of this is commonly red compact felſpar, incloſing cryſtals of felſpar and quartz.

3. Sienitic porphyry. This differs from the preceding in containing cryſtals of hornblende in addition to the other ingredients.

4. Pitchſtone porphyry. The baſe of this is pitchſtone, either red, green, brown, or black.

5. Clay porphyry, of which the baſe is indurated clay paſſing into hornſtone; it is generally of a reddiſh colour, and contains cryſtals of quartz and felſpar.

Mountains of porphyry are not ſtratified and never incloſe beds of other ſubſtances. Its texture is commonly compact but it occaſionally occurs in ſchiſtone. It is not very rich in mineral veins; the clay porphyry is the moſt ſo; the rich mines of Schemnitz in Hungary being in this ſpecies of rock.

The porphyritic formation is not very diſtinctly ſeparated from the other rock formations which accompany it, nor is its rank among the primitive mountains, with regard to antiquity, very clearly aſcertained.

Hornſtone porphyry ſeems to be the oldeſt of the claſs, and clay porphyry the moſt recent. The red porphyries are employed in ornamental

architecture for columns, &c. and are much esteemed.

PORZELLANERDE. See CLAY (*Porcelain.*)

POTASH *of Commerce*. See CARBONAT *of Potash*.

POTASH, *Vegetable Fixed Alkali*. *Gewachsalkali*. Germ.

The term potash, which originally signified one species of impure carbonat of potash, and is still applied to it in commerce, is restricted in the modern chemical nomenclature to the pure vegetable fixed alkali free from carbonic acid or any other admixture.

The sources of this alkali have been mentioned when describing its carbonat, and it is *procured* entirely from the vegetable kingdom, but Klaproth has discovered that it forms about a fifth part of the composition of leucite and lepidolite, and probably will be detected in many other minerals now that analysts are aware of its existence in the mineral kingdom, so that strictly speaking, the term *vegetable* as applied exclusively to this alkali is incorrect.

Potash is easily prepared in tolerable purity, but with difficulty absolutely so. For most purposes of chemical analysis the following way is sufficient.[a] Select a pure carbonat of potash, (made either by refining common pearlash, or by calcining cream of tartar, or deflagrating it with equal parts of nitre) boil it with sufficient water in a polished iron kettle with about half its weight of well burnt lime from white marble for a few minutes, strain the liquor through linen, wash the bulky mass of slacked and carbonated lime once with hot water to extract the adhering alkali, add it to the first liquor, and without waiting to filter it, reduce the whole by boiling till it is of a thick syrupy consistence; after which pass it once more through linen and set it by in a glass bottle. In a day or two the liquor becomes perfectly clear, and may then be poured off from the sediment, and kept in a well stopped glass bottle. Liquid potash thus prepared, if a very pure carbonat of potash be selected, will be sufficiently pure for most experiments. The use of the lime is to absorb the carbonic acid, and the precise quantity required for this purpose depends on the nature of the lime, and its perfect calcination. When too little lime has been used, the alkaline liquor still retains a portion of carbonic acid, and will therefore become turbid with lime or barytic water, (which turbidness will disappear on supersaturation by any acid, whereby the precipitate is distinguished from that formed by the presence of a sulphat). When too much lime has been employed, the ley contains lime in solution as well as perfectly caustic alkali, and will become turbid by adding carbonic acid or simply by blowing through it from the mouth for a time, or by a short exposure to the air. For the analysis of earths therefore it is better to have a small excess of carbonic acid, which effectually excludes lime. The lime should be of Carrara marble or oyster shells, which contain no alumine, as the latter earth is readily dissolved by the alkali, and is with difficulty got rid of. The actual quantity of alkali in a given solution is determined by evaporating it to dryness in a silver crucible, and weighing the white solid alkali that is left. Liquid alkali prepared in this way is known to be pure (that is, free from earth,) by super-saturating a little of it with *pure* nitric or muriatic acid, then adding carbonat of ammonia till it is sensibly ammoniacal, and boiling for a few minutes. If no earth be present no turbidness will ensue after standing for several hours.

Potash as commonly prepared however, often contains, besides the pure alkali, carbonic acid, sulphat and muriat of potash, manganese, silex, alumine, and oxyd of iron. Of these, the three first if not in any considerable quantity are often of no importance in the analysis of minerals, but it is necessary that the chemist should know that they exist, and when required should be able to free the alkali from them. The way of detecting the presence of earths has just been mentioned; the sulphuric acid may be shewn by first saturating the alkali by perfectly pure nitric or muriatic acid, and then applying a barytic test: and the muriatic acid may be discovered by first saturating with the nitric, and then precipitating the sulphuric acid (if any) by nitrat or acetite of barytes, and lastly testing with nitrat of silver. The way of preparing potash perfectly pure is by crystallization of the pure alkali either from the watery solution or from the solution in alcohol. There are however some slight objections to each mode, though both of them answer sufficiently well for all purposes when made with care.

When a solution of potash with the above impurities is evaporated gradually, as soon as it has reached a certain point of concentration, the sulphat and muriat of potash begin to separate, being much less soluble than the alkali itself, afterwards the carbonat of potash crystallizes, and lastly the pure alkali, and the form

[a] Klaproth.

of the latter cryſtals is ſo different from the reſt that they cannot be eaſily miſtaken. It ſhould always be remembered in theſe operations that potaſh is extremely greedy of carbonic acid, which it abſorbs from the air very ſpeedily, ſo that all evaporations ſhould be made as much as poſſible in narrow-mouthed veſſels, and at a boiling heat that the ſteam which is conſtantly paſſing off may preſerve the liquor from the contact of air. All ſlow evaporation in the open air is therefore entirely inadmiſſible, as it would allow the whole of the alkali to be converted into a carbonat.

M. Lowitz of Peterſburgh, has given very good directions for obtaining pure cryſtals of potaſh by ſimple evaporation of the cauſtic ley, and Berthollet has explained with his uſual accuracy the proceſs by alcohol. That of Lowitz is the following:[b] make a ſtrong ley with carbonat of potaſh and lime in the uſual way, ſtrain it through cloth and evaporate it at a boiling heat in a veſſel of very clean iron till a ſtrong pellicle appears on the ſurface. Cover the veſſel, and let the liquor cool, by which moſt of the neutral ſalts and carbonat of potaſh cryſtallize. Pour off the clear ſolution and evaporate it further, during which ſcum off from the ſurface the ſaline pellicle as long as it forms. When this has ceaſed, remove it from the fire and ſtir it inceſſantly till cold. Then rediſſolve it in twice its weight of cold water, filter the ſolution and evaporate it in a glaſs retort (or what is better, a cloſe veſſel of ſilver or ſilver-plate) till it begins to depoſit regular cryſtals which are now pure potaſh. When all the cryſtals have depoſited, ſeparate them from the liquor (which is always brown) let them drain in a cloſe veſſel, rediſſolve them and again cryſtallize them as before till they form with water a perfectly tranſparent ſolution. The liquor by further evaporation will furniſh more of the cryſtals of potaſh till it is almoſt exhauſted. Some nicety of management is required in the laſt proceſs, for if the ſolution be too much concentrated before it cools, the whole congeals into a ſolid white maſs, which muſt be a little diluted, and again brought to a boiling heat in order to cryſtallize.

The cryſtals of potaſh formed in this way aſſume the form of very thin broad plates croſſing each other in every direction, and ſo compleatly ſhutting in the mother liquor, that a bottle full of the mixture of cryſtals and ſolution may often be inverted without ſpilling a drop of the liquor. When melted in a red heat in a ſilver veſſel, theſe cryſtals run into a maſs of a ſnowy whiteneſs.

The other method of obtaining pure potaſh is by means of alcohol. Of all the ſubſtances contained in common potaſh, namely potaſh, carbonat of potaſh, alumine, ſilex, ſulphat and muriat of potaſh, only the firſt is to any notable degree ſoluble in well rectified alcohol, ſo that the purification of potaſh would appear to be effected by this means with perfect accuracy and ſimplicity, and is ſo to a great degree, though the curious reſearches of Berthollet on this ſubject ſhew that there are ſome decompoſitions that take place, which might not be at firſt ſuſpected. The experiments of this excellent chemiſt are the following.[d] A cauſtic ley was prepared in the uſual way from common carbonat of potaſh and lime, and was boiled down in an iron veſſel till it began to thicken. It was then put into a retort and alcohol was poured on it, and boiled for a while till part of the ſpirit had diſtilled over. When cold, the retort contained two diſtinct liquors, the loweſt was of a dark colour, and at the bottom of it were a number of ſaline cryſtals, (which proved to be carbonat of potaſh) mixed with a black earthy matter: the upper liquor was leſs coloured, and conſiſted chiefly of the alcohol holding the potaſh in ſolution. The lower liquor was a ſaturated ſolution of carbonat of potaſh in water, and ſtrongly effervesced with acids, and the earthy impurities were either obtained from the lime, or originally contained in the carbonat of potaſh employed. The alcoholic ſolution did not effervesce with acids nor precipitate lime water, but it ſlightly troubled muriat of barytes and gave a ſmall quantity of effervescing precipitate, which ſhewed that ſome carbonat of potaſh was ſtill contained. This ſolution was then boiled in a retort till part of the alcohol had diſtilled off, and on cooling it ſeparated into two liquors immiſcible by ſhaking, the upper part of which appeared like a yellow oil, and gave no longer any indication of carbonic acid, and was now a ſolution of as pure potaſh as could be obtained. By evaporation, and cooling at a certain point of concentration, clear cryſtals of potaſh ſeparated, but the mother liquor gradually aſſumed a darker colour. The lower of theſe two liquors alſo contained conſiderably pure potaſh, which cryſtallized by evaporation, but it was mixed with ſome carbonat of potaſh, and the ſolvent was chiefly water with a very little alcohol. If the entire alcoholic ſolution of potaſh is diſtilled to dryneſs

[b] An. Chim. tom. 22.

[d] Mem. de l'Acad. for 1783.

it becomes gradually of a very dark brown colour, and is then effervefcent, though it fhewed no traces of carbonic acid before the boiling. The pure cryftals of the alkali when fimply heated, lofe their water of cryftallization but do not acquire the property of effervefcing. But if thefe fame cryftals are diffolved in frefh alcohol, the folution which when cold is clear and colourlefs, turns yellow as foon as boiling, by evaporation the colour deepens, and even when highly concentrated it now refufes to cryftallize, and at laft when deficcated, if water is added, though the alkali is rediffolved, there remains a brownifh refinous infoluble matter.

The action of alcohol on potafh feems therefore to be the following: it firft diffolves the potafh, and feparates from it the greater part of the carbonated alkali which common potafh contains, but a fmall portion of it is retained till the folution is concentrated, when the more watery part of the alcohol feparates from the purer fpirit, and the carbonat of potafh follows the former.

But befides this, a feparate action is exerted by the potafh on the alcohol, whereby the fpirit is in part decompofed, and furnifhes both carbonic acid and a blackifh refinous matter, and thus the alkali is again rendered flightly effervefcent, and the folution by diffolving this refinous matter becomes high coloured.

This gradual formation of carbonic acid by the action of potafh on alcohol, which is not adverted to in Berthollet's original memoir, is fully proved by Pelletier, who fhews that the fame change will take place even without heat, when the folution is kept for a confiderable time, and the whole alkali is gradually changed to a carbonat.

From what has been obferved, it will follow that the alcohol fhould be allowed to remain only a fhort time on the potafh, and the pureft poffible alkali may be prepared fimply in the following way: felect a very pure carbonat of potafh, render it cauftic by lime, (leaving rather a little carbonic acid than an excefs of lime,) boil down the ley to drynefs, then add highly rectified alcohol, and boil the mixture for a minute or two, and fet it by in a well clofed veffel. Then pour off the alcoholic folution, evaporate it rapidly, and immediately bring it to perfect drynefs, which will leave a white faline mafs, fometimes covered with a black cruft which may be removed, and the reft is as pure potafh as can be required for chemical purpofes, containing no earth nor other foreign ingredient than a little of the refinous matter from the alcohol, which is of no importance in analyfis. Or if abfolute purity is required, the cryftals of potafh feparated from the alcoholic folution may be employed.

The method of affaying alkali for earth and carbonic acid has been mentioned, but it may be right to notice a caufe of miftake which may occur. If to a very concentrated folution of perfectly pure potafh in alcohol be added lime water, or muriated barytes, or barytic water, a precipitate will occur which might lead to fuppofe that carbonic acid was prefent, but in this cafe the precipitate is pure lime or barytes, and not a carbonated earth, which is feparated from its folvent by the alcohol of the folution, and is rediffolved on adding diftilled water, which the carbonated earth is not.

In preparing cauftic potafh it fhould be remembered that the folution of potafh at a boiling heat when highly concentrated, readily acts upon glafs, and foon diffolves a fufficient quantity materially to alter and impair its purity. In this cafe it gives a gelatinous precipitate with acids, which is the filex of the glafs. Therefore in preparing the alkali, all boiling and evaporating when the liquor is concentrated fhould be performed in bright iron veffels, or (for perfect purity) in thofe of filver or plated copper.

The alcohol diftilled off potafh carries up with it fufficient alkali to turn fyrup of violets green.[d]

Potafh is a fimple fubftance as far as has been hitherto examined, though there is fome reafon for fufpecting it to be a compound. When folid and dry it is a white falt intenfely acrid to the tafte, and corroding the fkin of the tongue almoft inftantly.

It exerts the fame action on every other part of the body, fo that when touched with the moiftened hand it has a greafy feel, owing to the inftant action which it begins upon the cuticle of the fingers. It is extremely foluble in water, and is one of the moft deliquefcent fubftances known and hence it is ufefully employed in experiments to abforb moifture from any gas in which it is confined. Along with moifture it abforbs carbonic acid with great rapidity.

Potafh melts at a moderately red heat and then runs into a clear liquid as thin as water, which becomes opake on cooling, and generally affumes a greenifh tinge, the caufe of which is not well known. At a full red heat (fuch as that of

[d] Berthollet.

melting copper) potash is readily volatilized, and flies off in a dense vapour which is easily perceived when a crucible holding it thus heated is suddenly uncovered. This vapour is potash unaltered.

Potash dissolves all earths with extreme facility by fusion, and even in watery solution with the assistance of heat. The mixture of potash and earth is soluble in water when the alkali is in excess, and the solution deposits the earth when saturated by an acid.

Potash when solid and deprived of its water of crystallization produces a sensible heat when mixed with water; but the *crystals* of potash form with snow or powdered ice one of the most powerful freezing mixtures that is known, and which is described under the article *Freezing*.

Potash unites with all acids, producing salts that are described under these articles respectively or those immediately succeeding. For the general properties which it possesses see *Alkali*: and for its action upon the *earths* in the moist or dry way upon *Oils*, *Sulphur*, *Phosphorus*, see these articles and those of *Soap* and *Glass*.

Potash when highly concentrated is very apt to cause glass phials in which it is kept to crack. It also seems to contract a very close union with glass in any form, so that the drop or two which wets the space between the stopper and the neck of the phial, will after a while cement it together so strongly as to require much pains and perseverance to separate them unless previously oiled.

An impure potash melted and cast into moulds, is used in surgery as a valuable and powerful caustic. It is mixed with soap, and applied in the form of a soft paste to the skin, and in some hours it destroys the life of the part to which it is applied, which portion after a while comes out in the form of a deep slough.

This alkali resembles soda so closely in taste, appearance, and general chemical properties, that they are not readily distinguishable in any other way than by uniting them with the several acids and examining the neutral salts resulting from this combination. The salts that are most readily distinguishable are the sulphats, nitrats, and tartrites. Thus the sulphat of potash is a hard bitter salt, requiring much water for solution, and therefore a saline precipitate of sulphat of potash is formed when the acid and alkaline solution are somewhat concentrated when added: whereas the sulphat of soda is very soluble, and differs essentially in its form of crystallization from the other. The nitrat of potash crystallizes in long six-sided prisms, but the nitrat of soda in cubes. The acid of tartar also is a very useful test. If the alkali to be examined is first dissolved in muriatic or any other acid, and a solution of tartareous acid added, if the salt has potash for its basis, there will be a precipitate of tartar in a few seconds, but the mixture will remain clear if the basis of the salt is soda. The nitro-muriat of platina also decomposes all salts with potash, but not with soda.

The affinities of potash are in the following order: the sulphuric acid, nitric, muriatic, phosphoric, fluoric, oxalic, tartaric, arsenic, succinic, citric, sulphureous, acetic, carbonic and prussic.

This order however, as in other cases of affinity, is to be taken with very considerable limitations, and in particular does not apply where the same acid forms both an acidulous and a neutral salt with potash, as in the case of the tartareous just mentioned, which will partially decompose even sulphat of potash, that is, to the point at which the acidulous tartrite is formed, but no further.

POTTER'S LEAD ORE is the term usually given to the common galena. See Lead.

POTTERY AND PORCELAIN.

Our limits would not allow us (even if we had the means) to enter into any detailed description of the antient and beautiful and most useful art of pottery, especially as the most essential part of it can hardly be called a chemical operation, though considerably connected with chemistry in many of the subordinate parts. We shall therefore give but a single example of the process by which a lump of plastic earth is converted into a hard brittle vessel, and add some observations on that part of the manufacture which is peculiarly destined for chemical uses.

The essential material of pottery is clay, which alone possesses the two requisite qualities first, of being in its natural state so plastic that with water it becomes a soft uniformly extensible mass, capable of taking and retaining any form, and secondly, that when it is thoroughly dried and has undergone a red heat for a time, it loses this plasticity, is no longer retentive of water to any considerable degree, becomes hard, close in texture, and able more or less perfectly to retain all liquids contained within its hollow.

The various composition of *Clay* has been described under that article and *Alumine*, and it has been there shewn, that though clay owes its plasticity to alumine, it seldom contains so much of this as of other earths, and is in fact a very compound substance.

Many of the impure coloured natural clays are of themſelves ſufficiently mixed with other earths for the potter's uſe without addition, but the white and finer clays moſtly require dilution with ſilex in one form or other, which can be done to a very conſiderable degree without taking away the plaſticity requiſite for working.

The moſt material circumſtances required to be conſidered in ſelecting the materials for pottery appear to be chiefly plaſticity, ſhrinkage, ſolidity, and compactneſs after drying; colour, and fuſibility.

The plaſticity ſeems to be ſimply owing to the quantity of clay uſed, that is to ſay, relatively to the original plaſticity of the clay itſelf, for this quality is not the ſame in all clays equally aluminous, but is much leſs in proportion in the indurated clays, and is increaſed by expoſure to air.

The texture, including the qualities of hardneſs and compactneſs, depends partly on the mixture of ſiliceous ingredient with the clay, and partly on the heat employed in the burning of the pottery. The purer natural clays are almoſt infuſible in any furnace-heat, their hardneſs is nearly progreſſive with the intenſity of the fire, but they have the eſſential defects of drying very ſlowly, of ſhrinking very conſiderably, and of becoming rifty or full of minute cracks when dried, ſo as on this account to be porous. It is therefore neceſſary to mix them intimately with any other earth of qualities oppoſite to thoſe of clay, that is, which abſorbs but little water and readily parts with it, (qualities directly oppoſite to plaſticity) and which dries compact and cloſe.

The colour of the earths uſed is alſo of eſſential importance in the finer pottery, in which the great deſideratum is to find a clay which *after burning* remains perfectly white. The appearance before burning cannot always be depended on, for though in general the whiteſt clays before burning are thoſe that remain white afterwards, it is only in a few diſtricts where clays are found that remain abſolutely white. Thus there is found at the foot of a range of high hills that directly overlook the Staffordſhire potteries, a ſtratum of white clay to appearance fully equal if not ſuperior to the beſt Devonſhire clays, but it cannot be employed for the fine pottery, as it acquires in burning a yellowiſh cream colour, which no art can correct. The colour is ſuppoſed to depend on iron.

The fuſibility of clays and other pottery earths is a ſubject of extreme importance as it is on this that the diſtinction between *Pottery* and *Porcelain* chiefly depends.

Under the article *Glaſs* we have treated at conſiderable length on the fuſibility of earthy mixtures, to which therefore we ſhall refer our readers. Porcelain may be defined to be a ſpecies of pottery ware compoſed of an earthy mixture which reſiſts compleat fuſion in a very conſiderable heat, but has been brought by a leſs heat than its melting point to a ſtate of incipient fuſion, and thereby acquired extreme hardneſs, ſonorouſneſs, ſemitranſparency, and a ſemi-conchoidal ſplintery fracture, approaching to the vitreous which is compleatly conchoidal. This laſt is quite a diſtinctive character between porcelain and pottery, for the fracture of the latter is ſimply granular. It appears probable therefore that no chemical action takes place in any pottery mixture till it arrives at the ſtate of porcelain. The moſt perfect and beautiful porcelains of Japan and China are compoſed (as appears from the beſt teſtimony) of one earth in which ſilex predominates, and which melts in a ſtrong fire, and of another which is infuſible *per ſe*, and by an union of theſe alone (as it appears) a porcelain is produced which ſcarcely vitrifies at the utmoſt furnace heat which art can produce. This ſubſtance has the united excellencies of being very hard, of a beautiful ſemi-tranſparence, very white where not artificially coloured, very tough and coheſive, ſo that it has ſtrength enough for the purpoſes for which it is deſigned when made very thin, and it bears ſudden heating and cooling without cracking.

Of the beautiful European porcelains which have been made in imitation of the oriental, it ſhould ſeem that none of them preciſely unites all its diſtinguiſhing qualities. Earthy mixtures have been made equally ſtrong, tough, and infuſible, and as truly porcellanous when burnt, but theſe have not exactly equalled the beſt Japaneſe in delicate whiteneſs and luſtre. But as the latter are the moſt eſſential qualities, that of infuſibility has been in general ſacrificed, (which indeed is of no conſequence for any of the common uſes of porcelain) and therefore thoſe that come up to the oriental in beauty and delicacy, of which there are ſeveral manufactures in different parts of Europe, for the moſt part ſoften and melt down in the moſt intenſe heat of a wind-furnace, at which the true Nankin and Japaneſe undergo no change.

The manufacture of the ordinary pottery is on the whole very ſimple, where the due ſelection of materials is made, but it is the more

delicate ornamental part, the modelling, enamelling, painting, gilding, &c. which displays so much exquisite beauty and which requires a combination of perseverance, skill, and practical nicety of management, that is hardly equalled in any other chemical manufacture.

The intimate mixture of the ingredients used in pottery is of great importance to the beauty, compactness and soundness of the ware. Formerly the wet clay and ground flint (or whatever was the other material) were beaten together with great and long-continued manual labour, no more water being added than was necessary to render the clay thoroughly plastic. This laborious (and therefore expensive) method has now been laid aside in the larger potteries, and the ingenious way has been substituted of bringing each material first to an impalpable powder, and diffusing them separately in as much water as will bring them to the consistence of thick cream, mixing them in due proportion by measure, and when thoroughly stirred together, evaporating the superfluous water till the mass is brought to a due consistence for working.

The following is the common process used in Staffordshire for making the ordinary ware. The materials are a fine clay brought chiefly from Devonshire, and a siliceous stone called *Chert*, or else common flint reduced to powder by heating red hot, quenching in water, and then grinding by wind-mills to a subtle powder. Each material is passed through fine brass sieves, then diffused in water, mixed by measure, and brought to a plastic state in the way just mentioned. A lump of this is then thrown on the potter's wheel, and by the workman's hands assisted by a small blunt iron knife-blade it is fashioned into the shape required, when circular, such as cups, saucers, plates, &c. but when made oval, or to any pattern form, it is moulded on a plaster model. Handles and spouts are then stuck on if required, and the piece after being again smoothed and the shape more accurately touched up, is set to dry for some days in a warm room, where it becomes so hard as to bear handling without altering its shape. When dry enough, it is enclosed along with many others in baked clay cases of the shape of band-boxes, called *seggars*, which are made of the coarse clays of the country. These are next ranged in the kiln or furnace so as to fill it except a space in the middle for the fuel. Here the ware is baked till it has remained fully red-hot for a considerable time, which in the larger kilns consumes 10 or 15 tons of coal, after which the fire is allowed to go out, and when all is cooled, the seggars are taken out and their contents unpacked. The entire contents of one kiln will sometimes exceed 30,000 different pieces of pottery. The ware is then in the state of *biscuit*; it is perfect pottery, very hard, beautifully white with a slight shade of yellow, and of a smooth surface, quite void of gloss, much resembling a clean egg-shell.

The next process is the glazing, which is performed on all pottery intended for domestic use. For this purpose the biscuit ware is dipped in a tub containing a mixture of about 60 parts of litharge, 10 of clay, and 20 of ground flint, diffused in water to a creamy consistence, and when taken out enough adheres to the piece to give an uniform glazing when again heated. The pieces are then again packed up in the saggars, with small bits of pottery interposed between each, and fixed in a kiln as before. The glazing mixture fuses at a very moderate heat and gives an uniform glossy coating, which finishes the process when it is intended for the common white ware. But the painting and gilding, each require separate processes.

Something may be added in this place on the pottery employed in chemical operations. Formerly when chemists made their own crucibles, muffles, &c. this was a very important branch of practical knowledge to every chemist, but at present this is almost wholly confined to the manufacturer, and we are only able to point out some of the leading circumstances which determine the goodness of pottery ware for one or other purpose.

Some very eminent chemists, among whom we may enumerate Glauber, Agricola, and Pott,[a] have paid particular attention to this subject, and that enlightened manufacturer, the late Mr. Wedgewood, has introduced a species of ware which answers some important purposes better than any hitherto invented.

Three important requisites are demanded to constitute a perfect pottery for all chemical purposes, namely, infusibility at any heat; compactness of texture so as to retain saline and other fluxes in fusion without being materially acted on by them, or allowing them to transpire; and endurance of sudden changes of temperature, particularly sudden heating without cracking or giving way in any degree.

These three requisites however have been found impracticable to be united in the same ware, which has led to the necessity of selecting

[a] Mem. de l'Acad. de Berlin, for 1750.

the species of ware according to the intended use. For enduring the highest heat without sinking, no vessels have been found so useful as the Hessian crucibles, which are made according to Pott, by mixing a very refractory clay with sand, the finest part of which is separated by a sieve and rejected. These vessels are not turned in the potter's wheel as common pottery is, but the clay is made into a much stiffer mass with less water, and is fashioned into the required shape by being strongly rammed into an iron mould. This gives them such a degree of compactness that they will retain saline fluxes for a considerable time.

With regard to this latter circumstance, no earthy mixture can be made which will not be acted on more or less by saline fluxes, and also by the vitrified metallic oxyds, as has been mentioned under the article *Glass*, and this is particularly the case with the vitrified oxyd of lead, which has long been used as a kind of test of the retentive power of crucibles, as it passes through the ordinary porous crucibles in a short time almost with as much ease as liquids through a sieve.

Ordinary crucibles may be made more retentive by being lined on the inside before they are quite dry with a thin coating of pure clay without any other mixture.

The most refractory material known is a mixture of unburnt with burnt clay, and one that resists the operation of saline fluxes longer than any other, and hence it is employed in the making of the large crucibles for the glass house as described under the article *Glass*. The close dense porcelain also retains saline matters long without being materially acted on.

It is of considerable importance in all fire-vessels that they should be able to bear heating and cooling with tolerable quickness, but it unfortunately happens that some of the most perfect ware in every other respect, is very deficient in this, and will even hardly bear the draught and flame of a wind furnace, however slowly heated, without danger of cracking. This is particularly the case with the valuable porcelain fire-ware invented by Mr. Wedgewood. This property of cracking on sudden changes of temperature, appears particularly to depend on the two circumstances of hardness and closeness of texture, and the latter is the greatest (ceteris paribus) in proportion to the fineness of division of the materials before burning. Thus in the ware just mentioned, both the clay and flint are brought to a most impalpable powder before mixture, and the texture is uncommonly hard and close; and on the other hand, it has been found necessary in making the best Hessian and other crucibles, to separate and *reject* the finer part of the siliceous ingredient, for the express purpose of enabling it to bear the strong draught of the wind furnace. The Wedgewood ware stands sudden heating and cooling better when it is covered with a thin coating of Windsor loam, or of a fire-lute composed of clay and coarse sand, and tow or horse-dung.

Crucibles intended merely for the fusion of metals, are much improved by a mixture of black lead. This material is protected from access of air by being involved in the clay, and is then incombustible, and its absolute infusibility and want of affinity with earths at any temperature, enable the clay to undergo a very high heat without melting. Besides the softness and smoothness of the plumbago enables the vessel to afford a very uniform surface without knots or projections, which in the common rough ware are apt to detain a portion of melted metal whilst pouring out. This ware will also bear sudden heating and cooling better than any other, so that scarcely any precaution is requisite on this account, but its softness and porousness render it quite unfit for holding any saline or other flux.

The most porous substance used for fire-vessels is bone-ash, which is therefore only employed when this quality is an advantage, as in the process of cupellation, already fully described under the article *Assay*. Here it acts like a sponge in absorbing the vitrified oxyd of lead, and only the reguline metal remains.

Of the earthen vessels intended to hold acid or corrosive liquors in distillation, no ware is so perfect as the white Wedgewood porcelain ware already mentioned, its texture being so close as not to require any lead-glazing. The only defect of this is the danger of cracking on any sudden change of temperature.

But even this as all other pottery ware when unglazed, becomes in some degree pervious when heated fully red-hot, so that it cannot be depended on at this heat to confine gasses when under any pressure. This accounts for the total disappearance of diamonds when enclosed in lumps of fine porcelain clay and baked in an intense fire, as was found in some of the earlier experiments on this substance, and could not be explained till the discovery of the total conversion of this gem into carbonic acid gas by combustion. This permeability of unglazed porcelain ware also explains some objections brought to the antiphlogistic theory by the

admixture of carbonic acid gas with azot when the latter is passed through red-hot porcelain tubes, which does not take place in glass tubes. The carbonic acid therefore arises from the burning fuel, and passes through the pores of the tube when red hot.

POTSTONE. *Topfstein*, Germ. *Pierre ollaire*, Fr.

The colour of this mineral is greenish grey. It occurs in mass. Its internal lustre is glistening and pearly. Its fracture is curved, foliated, and imperfectly slaty. Its fragments are tabular. It is often translucent on the edges. It is soft, is greasy to the touch; tough and difficultly frangible. It is found in beds with serpentine, at Como in the Grison country, and in Saxony. It may be turned in a lathe, and is made into a variety of vessels. It is also used as a lining for furnaces, being remarkably refractory.

POWDER OF CASSIUS. See Gold.

PRASE. See Quartz.

PRECIPITATE. *Niederschlag*, Germ.

A chemical precipitate properly means a visible *subsidence* of any substance from its clear solution, produced by any method whatever, and it is generally applied when the separation takes place in a flocculent or pulverulent form, in opposition to *crystallization*, which implies a similar separation in an angular polyhedral form. Thus even a mass of crystals may be termed a *precipitate*, when their subsidence is so sudden that their proper crystalline shape cannot be distinguished by the naked eye, as when Glauber's salt is suddenly separated in very minute crystals from its saturated watery solution by the affusion of alcohol.

But precipitation may be taken in a more extended sense to mean any visible separation of any substance or compound, from its clear solution, whether it sinks or swims, and whether it be crystallized or pulverulent, and it then forms one of the great operations in chemistry, and is directly opposed to that of solution; for in fact by far the greatest part of the operations of the chemist may be resolved into solution and precipitation.

The mode in which precipitation affects and modifies chemical *affinity*, has been mentioned under that article, and Berthollet has shewn in his valuable essays on chemical affinity and on chemical statics, how philosophers have been led to deduce the supposed order of affinities from the circumstances of precipitation.

The following remarks on the precipitations effected by acids or by alkalies and earths may be added from the same author.[a] The important subject of metallic precipitates will be noticed separately.

There are two principal kinds of precipitates which have been distinguished by chemistry, one where to a compound composed of an acid and a base, each highly soluble in water, another acid is added, which has a greater affinity with the base, and forms with it a compound less soluble than the first. In this case the precipitate (which is sometimes crystallized, sometimes otherwise) is composed of the acid last added, in proportions that vary but little. As for example when sulphuric acid is added to a saturated solution of nitrat of potash a crystallized precipitate of sulphat of potash is added, the *proportions* of which scarcely vary in any circumstances, though the actual *quantity* of precipitate is determined by the quantity of water and of sulphuric acid present.

Another kind of precipitate is that which has usually been supposed to be simple, and takes place when to a compound of an acid and a base insoluble (or nearly so) in water, an alkali or soluble earth is added, which by elective affinity unites with the acid, and displaces the former base; and this latter now supposed to be uncombined and insoluble in the quantity of liquid present, falls to the bottom. This kind of precipitation is constantly resorted to when we wish to obtain the simple earths, as in adding an alkali to a solution of alum in order to precipitate the alumine, to Epsom salt to precipitate magnesia, &c. But the precipitate in all such cases is not (as has been usually supposed) the simple earth, but it always retains after the first operation a small and variable portion of the acid with which it was before combined. Thus if the alumine, however well edulcorated, be redissolved in muriatic acid, and a salt of barytes added, there will be a sensible precipitate of sulphat of barytes. This *retent* of acid is variable and may be reduced to an insensible quantity, if not absolutely taken away, by subsequent digestion in very concentrated alkali. Such precipitations therefore are not effected merely by simple affinity, but by a division of the acid into two portions, one of which, and by much the largest, goes to the alkali, and the other remains with the earth and accompanies it in its precipitation. Even when no precipitation occurs, the acid may be proved to distribute itself in this manner, for as Bergman has remarked, if a calcareous salt is

[a] Chemical statics, vol. I.

diſſolved in fifty times its weight of water, and an exceſs of potaſh or ſoda is added, no precipitation takes place, ſo that the acid continues in part to act upon the lime and renders it ſoluble in a much leſs quantity of water than the lime alone would require for ſolution.

It may be aſſumed therefore as a general principle, and one which is of great importance in the explanation of chemical decompoſition, that where a ſalt is compoſed of an acid and a baſe, inſoluble or little ſoluble by itſelf, the decompoſition effected by any ſoluble baſe is the reſult not of a ſimple but a compound action, in which on the one hand the decompoſing baſe unites with more or leſs of the acid and remains in ſolution, whilſt the other baſe reſumes its inſolubility by the ſeparation of part of its acid, and forms a precipitate with the remainder. This will be found to apply ſtill more ſtrikingly in the formation of metallic precipitates, and of thoſe ſalts which (like the ſub-ſulphat of mercury or turbith) were formerly taken for ſimple oxyds, but are now found to be ſalts with exceſs of oxyd.

Chemical affinity is in many caſes determined by precipitation, but a contradiction in the mode of applying this principle has been well pointed out by Berthollet.

The orders of affinity which the ſeveral baſes have for the acids is uſually determined by adding any baſe to a known combination of an acid and another baſe, and if the latter baſe is precipitated it has been inferred that its affinity for the acid is leſs than that of the other baſe. Thus when lime is precipitated by adding potaſh to muriat of lime, it is inferred that potaſh has a ſtronger affinity for muriatic acid than lime, and hence the preference in the order of affinity has been given to the moſt ſoluble baſes. But on the other hand, the reſpective affinities of the acids has been determined in the contrary way, as for example, when oxalic acid is added to muriat of lime a precipitate of oxalat of lime is produced, whence the ſuperior affinity of the oxalic acid over the muriatic for lime has been deduced. Thus in theſe caſes the preference in affinity has been given to thoſe acids which have the moſt diſpoſition to form inſoluble combinations.

But many inſtances may be given to ſhew that the phenomena of precipitation are diſtinct from thoſe of chemical affinity, ſo that the reſulting inſolubility or force of coheſion which produces precipitations is ſometimes ſuperadded to the ſimple force of affinity, and at other times oppoſed to it, and ought in ſtrictneſs to be always conſidered as a diſtinct principle.

Of Metallic Precipitates.

The metal of every metallic ſolution in any acid is always in the ſtate of an oxyd, ſo that the ſolution muſt contain at leaſt three ſubſtances, the acid, the metal, and oxygen united with the metal. But the proportion of the latter is ſubject to a great number of variations, and is different both with the ſeveral metals and with the ſame metal in different circumſtances.

A metallic ſolution may be decompoſed and its metallic part precipitated either in the reguline ſtate or as an oxyd, and theſe two methods, which have each been adopted in the analyſis of metallic bodies, require to be conſidered ſeparately.

When a carbonated alkali is added to a metallic ſolution, the precipitate is a carbonated oxyd of the metal, and like the other carbonats effervеſces on the addition of a ſtronger acid. But when a pure alkali is added only to ſaturation, the precipitate is in ſome inſtances nearly a pure oxyd, but in the greater number is an oxyd retaining a ſmall portion of the acid with which it was united. This acid however is not ſufficient to render it ſoluble and it may be generally entirely taken away by ſubſequent digeſtion in a concentrated fixed alkali provided the oxyd is not ſoluble therein.

The firſt action of alkalies therefore on moſt metallic ſolutions is to cauſe an unequal diviſion of the acid, the greater part of which unites with the alkali, and the remainder falls down along with the oxyd now rendered inſoluble. If ammonia be the alkali employed, there is alſo in general a partition of the alkali, and the precipitate is a quadruple compound, of the metal, the oxygen united with it, and a ſmall portion of the acid, and of the ammonia; and the ſolution contains the greater part of the acid, of the alkali, and often a ſmall part of the metallic oxyd ſufficient to be very ſenſible to the taſte, and to chemical teſts. According to Prouſt, lime alſo when uſed as a precipitant enters in a ſmall proportion into the precipitate.

Metallic ſolutions ſometimes yield precipitates on the mere addition of water, by the ſimple diſtribution of the conſtituents into two portions, a ſoluble and an inſoluble one, the former of which has an exceſs of acid, and the latter of oxyd. Thus when the clear nitrat of biſmuth is diluted with water a white precipitate falls down which is chiefly oxyd of biſmuth, and the ſupernatant liquor contains an exceſs of

acid and a small portion of metal which may be separated by evaporation or by an alkali. In like manner if sulphuric acid and mercury are treated together, sulphureous acid is given out, and the white mass that remains is an uniform acid sulphat, which deliquesces into a dense solution. But if hot water be added, the *turbeth* or yellow *sub-sulphat* of mercury is precipitated, and the solution contains an acid sulphat. Even the first turbith may be further decomposed by a fresh affusion of hot water dividing it into a turbith still more loaded with oxyd, and an acid solution.

These, and many other facts which might be adduced, illustrate the general law of decomposition by precipitation, and the constant tendency of metallic salts to divide into two compounds, each consisting of both the constituents of the salt but distributed in unequal proportions. These phenomena are rendered still more complex by the addition of new substances, most of which being described under the respective metals, a repetition in this place would be needless.

The second species of metallic precipitates are those in which the metal appears in its reguline form. This takes place when one metal is precipitated by another, as when a piece of iron is immersed in a solution of copper, and also when phosphorus is kept for some time in certain metallic solutions.

Before the discovery of oxygen, and of the oxydation of metals being necessary to their solution in acids, the precipitation of one metal by another was supposed to be produced by simple elective attraction, and the respective affinities of the metals for the acids was put down in the order of the precipitations which they produced. But this explanation though true in general, does not explain a number of apparent anomalies in metallic precipitation, so that we must take into consideration the force of other agents and other affinities.

The order of the precipitation of one metal by another is the following, among those that have been the most accurately examined, viz. zinc,[a] iron, lead, tin, copper, silver, mercury, gold; that is to say, zinc precipitates all the other metals; iron precipitates all but zinc; lead all but zinc and iron, &c.

But sometimes the precipitation fails with solutions in one acid, though it succeeds with others; thus zinc separates iron in the metallic state from muriat of iron, but only as an oxyd from the nitrat. A small excess of acid is necessary to begin the process in all cases.

During this operation the following affinities must act, namely, that of the precipitant (or metal by which the separation is effected) for the oxygen of the metal already dissolved; that of the oxyd thus produced, for the acid of the solution; and to this Berthollet adds, that of the two metals for each other when in the reguline state. The sum of these affinities must overcome that which exists between the constituent parts of the metallic salt intended to be decomposed.[b]

It is possible therefore that no precipitation may take place even when the metal added has a greater affinity for oxygen than that already dissolved, if the oxyd of the former metal has a less affinity for the acid than the oxyd of the latter has. And on the other hand a precipitation may be effected even if the precipitant has less affinity for oxygen than the metal already dissolved, provided its oxyd has a greater affinity for the acid. In this latter case however there must be a considerable excess of acid present in order to begin the oxydation of the precipitant. Thus, again, it is explained why a precipitation will take place with the solution in one acid, and not in another, since the acids themselves differ considerably in their affinity for the same metallic oxyd, so that in the first case, this affinity may surpass that of the same acid for the metallic oxyd already dissolved, and in the second may fall short of it.

Still however (as Berthollet remarks) if the only active affinities in these cases were those of the metals for oxygen and the oxyds for acids, it is not probable that the reduction of the metal whose affinities were the weakest, would be complete, but in all probability there would be only an unequal partition of the acid and oxygen, so as to produce the *more* oxygenated salts of one metal, and the *less* oxygenated salts of the other metal, which would be agreeable to the usual mode of action in similar cases. Hence it becomes necessary to recur to the well-known affinity which exists between the metals themselves, and many facts shew that this is concerned in these processes.

For example when a plate of polished copper is dipped into a solution of nitrated mercury, it is instantly whitened by the mercury precipitated upon its surface, but this metal is not merely deposited upon the copper, but amalgamated with it, so that it cannot be scraped or

[a] Bergman. [b] Vauquelin, An. Chim. xxviii. p. 40.

rubbed off, but can only be separated by fire. Here then the affinity of the mercury for the copper must act forcibly in causing its separation from the nitric acid which held it in solution. In like manner when copper is immersed in a solution of silver, the precipitated metal is not pure silver, but an alloy, containing a very small portion of copper. As this mutual affinity existing between the metals varies according to the metal employed, this also explains why iron (for example) precipitates silver from its solution with much more difficulty than copper, though iron has a much stronger affinity for oxygen than copper (as is proved by the precipitation of copper by iron) for the affinity between silver and copper is much stronger than between silver and iron.

As then metallic precipitates are in fact alloys (though often with such a small proportion of the precipitant as to be scarcely sensible) it is necessary that the combination of the metals must first be made when both are in solution, for we can conceive of no other method by which two solid metals (copper and iron, for example) should be alloyed in a common temperature. The whole process therefore must be the following, taking the above metals as instances; a portion of the iron must first be oxydated and dissolve in the acid, and by this it disoxydates and precipitates in the metallic form an equivalent portion of the copper, during which time the dissolved iron must divide itself into two very unequal portions, of which by far the largest part remains in solution, but the remainder must return to the metallic state to unite with the copper and to be precipitated along with it. This complicated action must take place even from the first, for how else can the union of the two metals be accounted for? and still less can it be explained without this supposition, as the precipitation proceeds, when the surface in contact with every fresh stratum of precipitate is no longer iron, but an alloy of copper and iron almost approaching to pure copper.

This leads us also to consider what is the affinity that determines the place to which the precipitates attach themselves. In the first instance, that is, when a surface of pure iron is exposed to the cupreous solution, the precipitate may be supposed to attach itself to the iron rather than to fall down loose in the vessel on account of the affinity existing between iron and copper alloyed with a little iron; but after the surface of the iron bar is covered, each successive stratum of precipitate attaches itself not to the iron (for this is covered) but to the surface of the precipitate already formed, that is to say, to a substance of exactly the same composition as itself. In this latter case therefore, the same kind of affinity acts as when a saline solution during crystallization deposits its crystals on the portion of salt already separated, rather than on a naked surface. The adhesion in this instance, however, is very slight, and readily broken. The proportion of the precipitant which enters into the alloy is probably greater in the first stratum of precipitate than in the subsequent ones; thus when copper is separated by iron, the part immediately in contact with the iron is visibly browner than the rest, owing probably to a larger admixture of iron.

It has been mentioned that phosphorus will seperate some metals from their solutions in the reguline state. These are particularly gold, silver, mercury, and copper. If a stick of clean newly-melted phosphorus is immersed in an acidulated solution of sulphat of copper, in a day or two it becomes beautifully spangled with little knobs of bright metallic copper, which gradually increase to a thick crust, after which if the stick is put into boiling water, the phosphorus will melt out, and leave a delicate hollow cylinder of copper. In this case however, as in the former, the precipitate is not pure copper, but an alloy of copper with phosphorus, or a phosphuret, in which however the quantity of phosphorus is extremely small, and the solution contains phosphoric acid. When phosphorus is introduced into a solution of mercury, only part of this metal assumes the metallic form, and the rest is oxyd combined with phosphorus and phosphoric acid.

From what has been observed above it is obvious that the method of recovering one metal from its solution by the addition of another, which is so often resorted to in analysis, requires considerable precaution, is liable to many inaccuracies, and can only be employed with propriety in certain cases. The circumstances which forbid its use, or render it inconvenient, are the following.[a] 1st. Where the salt formed by the union of the precipitant in the acid is insoluble in water, and will mix with the precipitated metal from which it cannot be readily separated, as when sulphat of copper is decomposed by lead, antimony, or mercury, for the sulphats of these metals are little soluble in water: or 2ndly, where the newly formed salt

[a] Vauquelin.

would be decomposed by the water, as when any nitrated solution is precipitated by bismuth: or 3dly, when the whole of the new oxyd formed by the transfer of oxygen from the precipitated metal to the precipitant cannot be dissolved by the acid present, as when nitrat of copper is decomposed by lead, in which case the precipitate will be very *largely* alloyed by the precipitant; or 4thly, when the affinities of the precipitant are such as more easily to decompose the acid than to absorb the oxygen of the metal already dissolved, as when nitrat of copper is decomposed by zinc, in which case the precipitate is partly reguline and partly oxydated; and 5thly, where the affinities between the two metals are so strong that the precipitate is *largely* alloyed with the precipitant, as when a solution of silver is decomposed by mercury.

Of these five cases, the 3d is probably that which much more contributes to produce a large alloy of the precipitated metal than even the affinity existing between the two metals; thus Vauquelin found that 50 grs. of copper, dissolved in nitric acid even with excess of acid required no less than 216 grs. of lead for its compleat separation, and the precipitate, instead of weighing only 50 grs. amounted to 128 grs. of which therefore 50 were copper, and 78 were lead. Yet these two metals have but little affinity for each other. This inconvenience is corrected, though not entirely removed by adding a considerable excess of acid.

PRECIPITATE, *white*, } are all oxyds or
PRECIPITATE, *red*, } salts of MERCURY,
PRECIPITATE, *per se* } *which see*.

PRECIPITATE, *purple*, *of Cassius*. See GOLD.

PREHNITE.

Its colour is pale green, either whitish, greyish, or yellowish. It occurs generally in mass, but is sometimes crystallized in oblique quadrilateral prisms.

The crystals are either single or aggregated; and are small or middle sized. Externally they are smooth and shining; internally they have a glistening pearly lustre.

The fracture is foliated or divergingly radiated; the fragments are indeterminately angular and wedge-shaped. It is translucent, but sometimes is nearly transparent. It is somewhat harder than glass, and is easily frangible. Sp. gr. 2.6 to 2.94.

Before the blowpipe it boils and melts into a yellowish brown enamel, but it does not become gelatinous with acids, in which respect it differs from zeolite with which it has otherwise a considerable resemblance.

The prehnite of the Cape of Good Hope has been analysed by Klaproth, and that of France by Hassenfratz, with the following results.

Klapr.		Hass.	
43.83	—	50.	Silex.
30.33	—	20.4	Alumine.
18.33	—	23.3	Lime.
5.66	—	4.9	Oxyd of iron.
1.83	—	0.9	Water.
0.	—	0.5	Magnesia.
99.98		100.0	

It occurs in veins in primitive slaty grunstein, also in rocks of the most recent floetz trap formation. It was first discovered by Col. Prehn at the Cape of Good Hope, and has since been found in Dauphiné in France, in the valley of Fassa in the Tyrol, also in Arthur's Seat near Edinburgh, and in other parts of Scotland.

PRINCE'S METAL. See COPPER, Alloys of.

PROBIERSTEIN. See KIESELSCHIEFER.

PROOF BOTTLE, an article of chemical apparatus; for an account of which see the Appendix.

PRUSSIAN BLUE, *Berlinerblau*, Germ.

PRUSSIC ACID, *Blausaure*, Germ.

Prussian Blue is a pigment of a beautiful dark blue colour which was discovered about the year 1710 by a chemist of Berlin of the name of Diesbach by the accidental mixture of a solution of vitriol of iron with an alkali which had been highly impregnated with animal matter. This discovery led to the preparation of this substance as a pigment, but the precise process was long kept secret till it was made known in the Philosophical Transactions for 1724, by Dr. Woodward. This has been adopted with some variations by succeeding chemists.

The process of preparing Prussian blue as given by Macquer, in his valuable memoir on the subject, is the following: prepare a quantity of bullock's blood by moderate drying, till it is reduced to powder, mix four ounces of this with as much carbonat of potash (made by calcining equal parts of nitre and tartar) put the whole in a covered crucible with a small hole at the top, and calcine it in a moderate fire till no more smoke or flame issues through the hole, at which time the mass will be black and carbonaceous; then raise the heat till the whole is moderately red, and remove it

from the fire. Then take out the contents of the crucible, and boil them for half an hour with two quarts of water and filter the liquor. Add to this immediately a folution of two ounces of vitriol of iron and eight ounces of alum in two quarts of boiling water, which will caufe a great effervefcence, and a copious depofit of a blue-green precipitate. Separate this latter by filtration, and add to it a few ounces of muriatic acid with much ftirring, which will immediately change the colour from blue-green to a deep blue. The quantity of acid is to be determined by the effect produced. The precipitate after ftanding for a day is then thoroughly wafhed and flowly dried, and is the Pruffian blue.

This with fome variations in the proportions of ingredients and in the exact manipulation is faid to be the ufual way of preparing this pigment in manufacture, and will always fucceed to a certain degree. Neverthelefs feveral chemifts who have exactly followed it in the large way for the purpofe of fale, have been difappointed in the quantity yielded, and have not always fucceeded in the quality of the article, fo that it is probable that there are fome particulars in the manipulation, &c. which are only known to the manufacturers.

It is immaterial whether the alkali ufed in the calcination with blood is cauftic or carbonated, fo that the latter is always employed. Any good pearlafh will anfwer the purpofe, and it is better to ufe from two to three times as much dried blood.

This procefs confifts effentially of two operations, one, the impregnation of the alkali with that peculiar principle contained in the blood (and in moft other animal matters) which gives the power of ftriking a blue colour with iron, and is called the *Pruffic Acid*; and the other, of partially decompofing this alkaline pruffiat by the mixed fulphats of iron and alumine, and uniting thereto the oxyd of iron and the alumine feparated by the alkali. The ufe of the muriatic acid in finifhing the procefs, appears to be (as we fhall prefently mention) chiefly to diffolve out the fuperfluous oxyd of iron, and bring the whole to that fine blue colour for which this fubftance is fo much admired.

The firft lixivium of the alkali after being calcined with the blood, was formerly termed *Phlogifticated Alkali*.

Pruffian blue as commonly prepared is a very compounded fubftance, confifting of the Pruffic acid, of oxyd of iron, generally of potafh and of alumine, but the two laft of thefe are in no degree effential to the Pruffian blue, chemically fpeaking, as the folution of fulphat of iron alone will produce it of as fine a colour, and as perfect a chemical compound. The alumine may be entirely put out of the queftion, as the fubject is fufficiently complicated without it, and its ufe feems chiefly to be to give a body to the colour (as in preparing the alum lakes) and perhaps to render it more convenient for the painter's ufe.

The inveftigation of the properties of this moft fingular fubftance, is perhaps, one of the moft perplexing in chemiftry, as the fubftance called Pruffic acid, is quite *fui generis*, and exercifes affinities which are remarkably complicated, and fcarcely to be explained by analogy with any other known body.

Macquer in a very elaborate enquiry explained fome of the moft important combinations of this fubftance, but little was known concerning the intimate nature of Pruffic acid, before the moft admirable refearches of Scheele, who, with an intelligence and fagacity peculiar to himfelf, devifed and performed a number of experiments on this fingular fubftance which immediately explained many of its moft important properties, and opened the way to the fine experiments of Berthollet and fucceeding chemifts.

Pruffian blue is infoluble in water and in acids. Though the lixivium from which it is formed is made at a red heat, the Pruffian blue itfelf is entirely decompofed at this temperature giving out carbonated hydrogen and carbonic acid, and the oxyd of iron and alkali are left behind.

We cannot follow a better order in our account of this fingular fubftance, than by firft giving a fhort abftract of the experiments of the illuftrious Swedifh chemift.[a] He firft examined the *lixivium fanguinis*, or liquor obtained by diffolving in water all the foluble part of the mafs of calcined blood and alkali, before the folution of vitriol of iron is added. This lixivium, compofed of Pruffic acid and potafh, foon lofes its power of forming Pruffian blue with folution of iron when it has been expofed to air. This the author conjectured might be owing to the carbonic acid of the atmofphere, which fuppofition was confirmed by confining a little of it in an atmofphere of fixed air for a day, after which the oxyd of iron produced by adding vitriol of iron to it,

[a] Scheele's Effays on Pruffian Blue.

was again soluble in acids, and was therefore not prussiated iron, so that the lixivium had been converted into simple carbonated potash. This was owing to the carbonic acid confined with it having united with the potash, and displaced the prussic acid which was volatilized. The Prussic acid therefore is shewn to have less affinity for alkalies than even the carbonic, and to assume the gaseous form when expelled from its base. Some of the *lixivium sanguinis* was then first mixed with a little vitriolated iron, which turned it yellow, and afterwards exposed to carbonic acid as in the former case, but now the prussic acid was not expelled, so that it still was able to form a perfect Prussian blue by a further addition of vitriolated iron, and subsequent washing with muriatic acid. Another portion of the lixivium was boiled for some minutes with the green oxyd produced by decomposing vitriolated iron by an alkali added when still wet, and this was exposed to the air for some time, but it still retained its power of forming Prussian blue. On the other hand, when another portion was boiled with the fully oxydated calx of iron from a nitrous solution, none of the metal was taken up, and the lixivium then lost its Prussic acid by short exposure to air. Hence the important fact is proved, that the presence of iron is necessary to give fixity to the prussic acid though already combined with an alkali, and to prevent it from being speedily dissipated by the weakest agents, even by the carbonic acid of the air.

To detect more fully the volatilization of the prussic acid when not detained by iron, this chemist suspended over the simple lixivium some paper first dipped in vitriolated iron, and then pencilled with alkali, and after two hours exposure on dropping muriatic acid on the spot, it became covered with the finest Prussian blue.

These experiments led to the attempt to obtain the prussic acid perfectly free from all combination. For this purpose the lixivium sanguinis (without iron) was supersaturated with sulphuric acid, and distilled from a glass retort with a gentle heat. When one-third had passed over into the receiver it was examined. It was a watery liquor with a peculiar taste and smell like peach-flowers, but it had detained only a part of the prussic acid expelled, as the air in and around the vessels was strongly impregnated with the volatile acid, and turned paper blue that had been dipped in an iron solution and alkali, as in the case already mentioned. But enough of the acid was detained by the water to be clearly detected by the iron test. The prussic acid of this aqueous solution was still more volatile than in the lixivium, as might be expected, and was entirely dissipated by a short exposure to air. In distilling this liquor the process may be stopped after about a third has come over, as this contains all the prussic acid. It also holds a little of the sulphuric acid (as detected by precipitating a barytic solution) so as to redden litmus, which the pure prussic acid will not do.

It was then attempted to procure this acid from the prussian blue itself, or rather from that yellow crystallized salt obtained by digesting the blue with caustic alkali in the way that will be afterwards described. This is a triple salt composed of prussic acid, potash, and oxyd of iron, and therefore one in which the iron serves as a bond of union between the acid and alkali. It contains less oxyd of iron than the prussian blue, and hence whenever any portion of its prussic acid is abstracted, the remainder is liable to pass into the state of prussian blue. This salt should be termed in strictness *prussiat of potash and iron*, to distinguish it from the simple prussiat of potash, such as exists in the *lixivium sanguinis*, but as the latter is seldom prepared, the triple prussiat above mentioned has got the name simply of *prussiat of potash*, which we shall here retain.

To obtain the acid from this salt, an ounce of it was dissolved in four parts of water, to which were added three drachms of sulphuric acid, and the whole was put into a retort with a close receiver. As soon as the mass began to boil, it grew thick, and a great quantity of prussian blue was separated. The distillation was continued till an ounce of liquor had passed over, which proved to be pure prussic acid simply dissolved in water, and all the vessels were also full of the vaporized prussic acid. The blue mass in the retort was then filtered, by which a clear liquor (which contained merely sulphat of potash) was separated, and the prussian blue remained on the filter. This blue was again boiled with caustic potash, to convert it into prussiat of potash, and distilled with sulphuric acid as before, during which precisely the same phenomena took place as at first, prussiated water and gas were distilled, and some prussian blue and sulphat of potash were formed. The same was repeated a third time, with similar appearances, only that the quantity of regenerated blue was now very minute, so that it appears that by a succession of these operations all the prussic acid may be expelled from the prussiat.

But this method of obtaining pure prussic

acid being troublesome and imperfect, (owing to the constant regeneration of prussian blue) the same excellent chemist discovered a still better way, and which is the one now followed. When prussiat of potash or prussian blue is digested with any oxyd of mercury, the prussic acid unites with this metal, and a soluble prussiat of mercury is formed which cannot be decomposed singly by acids or alkalies, and may be brought to crystallize by evaporation. When this prussiat is digested with metallic iron the first action of the iron is to deprive the mercury of its oxygen, and precipitate it visibly in the metallic state; and the prussic acid is set at liberty. This however would immediately unite with the iron if it were not prevented by the presence of a stronger acid, for which the sulphuric (or indeed any other) may be added. Then on applying heat, the disengaged prussic acid rises in distillation with the first water that comes over, and may be collected. The exact process of Scheele is the following: to two ounces of prussian blue mixed with one ounce of red mercurial precipitate, 6 oz. of water were added, and the whole was boiled for some minutes with constant agitation, when the blue colour entirely disappeared, and the mass became of a yellowish grey. It was then filtered, and the mass on the filter edulcorated with a little hot water which was added to the clear liquor. This, which had a strong mercurial taste and was pure prussiat of mercury, was then poured upon $1\frac{1}{2}$ oz. of clean iron filings, to which were added 3 drams of strong sulphuric acid. The whole was well agitated, and in a few minutes it was turned quite black by the reduced quicksilver, and at the same time lost its mercurial taste and acquired the peculiar peach-flower smell of free prussic acid. The liquor, poured off from the mercury that had subsided, was then put into a retort, and a fourth part of it was distilled over into a well luted receiver, and this liquor was now aqueous prussic acid, with no other admixture than that of a little sulphuric acid which had risen along with it. This was got rid of by mixing it with a little chalk, and a second distillation. Probably barytic water would be preferable, as every distillation volatilizes and destroys a portion of the prussic acid.

There appears at first sight a contradiction in the order of affinities between prussic acid, iron, and mercury respectively, when it is found on the one hand that oxyd of mercury decomposes prussian blue, and takes this acid from the iron and potash with which it is united; and on the other hand when iron filings again compleatly decompose prussiat of mercury. Berthollet explains this apparent contradiction by alledging that the *oxyd* of mercury has a stronger affinity for this acid than the *oxyd* of iron, even combined with potash, and hence any mercurial oxyd or salt will decompose prussian blue and give a pure prussiated mercury; but on the other hand iron has a greater affinity for oxygen than mercury has, and hence *metallic* iron decomposes the oxyd of mercury existing in the prussiat, and the mercury, now brought to the metallic state, separates from the solution.

We shall now describe the properties of this acid and its composition, and afterwards proceed to its combinations, in which it will be necessary in some degree to return to those prussiats of iron and potash which have been already partially described.

The Prussic Acid, (the preparation of which in a liquid form has been already described) has a sweetish and acrid taste, and a smell resembling that of peach-flowers or bitter almonds; nor is this latter circumstance a mere coincidence, since this acid is actually found in many parts of vegetables. It is strongly poisonous. It does not redden vegetable blues, and hence, as well as from the absence of sourness of taste, it is very doubtful how far it ought to be entitled to the name of an acid, though from its property of neutralizing alkalies and forming crystallizable salts with them, and with metallic oxyds, it is more conveniently classed among these bodies. It does not appear to contain any oxygen. It precipitates sulphurets, and curdles soap. It is extremely volatile when simply united with water, or with an alkaline base singly, and is expelled from the latter by every known acid, and even by light, and by a moderate heat. It cannot be crystallized.

It has no action upon metals, but unites with their oxyds, forming combinations for the most part insoluble, and not easily decomposable by other acids. It has the greatest tendency to form triple salts when in contact with an alkali and a metallic base, and it adheres to the alkalies and earths with much more force when also united to a metallic oxyd (particularly of iron) than when only in single combination. It is totally decomposed by oxymuriatic acid. The double and triple salts formed by this acid with the different bases will be presently described, but we shall first mention the experiments of

Scheele, Berthollet, and others, which lead to an explanation of the nature of this singular substance.

Those of Scheele were the following (among many others of less importance).

Some pure prussian blue was prepared and distilled *per se* in a retort, to which was attached a receiver containing a little water. The fire was urged till the retort was red-hot. The water in the receiver contained some undecomposed prussic acid, and ammonia, and the air of the vessel was impregnated with the volatile acid, and with carbonic acid gas. The mass that remained in the retort was black and magnetical. Hence ammonia appeared to be one of the constituents of prussic acid, and the other the author was at first disposed to believe to be an animal oil. He then endeavoured to compose prussian blue by uniting ammonia with some oily matter by distillation of this alkali with fat, lard, oil of turpentine, &c. but to no purpose. This led to the further conjecture that it was the carbonaceous part of the oil alone that was essential, which was confirmed by the following experiments: two crucibles were filled with a mixture of charcoal powder and alkali of tartar, and kept for a quarter of an hour at a red-heat. The contents of one were then thrown into water, but into the other some dry muriated ammonia was stirred in, and heated for a minute or two till no more ammoniacal vapours were given out. This was then lixiviated with water. On trying the lixivium from the first crucible, with vitriol of iron, and acids, scarcely any sensible quantity of prussian blue was obtained: but the second gave it in abundance. In another experiment, plumbago was substituted to the charcoal, and after calcination with potash and sal-ammoniac, it yielded prussian blue. From these interesting experiments it appears that the prussic acid is generated by some peculiar action of charcoal on ammonia, assisted, doubtless, by the operation of potash, or in other words, that it is, probably, ammonia intimately combined with carbon. Hence when prussian blue is mixed with six times its weight of black oxyd of manganese and distilled, nothing but carbonated ammonia comes over into the receiver.

Berthollet pursued these ingenious researches, calling in the assistance of another and most powerful agent, the oxymuriatic acid. If this acid is mixed with liquid prussic acid prepared in the way given by Scheele, the oxymuriatic acid loses its peculiar suffocating smell, and becomes common muriatic acid, whilst the liquor acquires a much more pungent odour, and appears to have become more volatile, and its affinity for alkalies to be lessened. In this state the precipitate which it forms with the solutions of iron, is at first green, but turns blue by the action of light, or by sulphureous acid, that is (probably) by losing a part of its oxygen. When sulphat of iron is mixed with oxymuriatic acid, and prussiat of potash is added, the green precipitate first formed is redissolved, but may be changed to the common insoluble blue prussiat by simple sulphat of iron, or iron filings, or sulphureous acid. If prussic acid is fully impregnated with the oxymuriatic and then exposed to the light, its properties as prussic acid are destroyed, and new ones are acquired. It now no longer combines with iron, and assumes quite a different and very peculiar smell, and when shaken with water, a great part collects at the bottom on standing for a few seconds, and resembles in appearance an essential oil. This singular substance however is not inflammable, but at a moderate increase of heat it resolves into a vapour immiscible with water. If left to itself, in time it crystallizes, but the nature of these crystals is not known.

Though prussic acid at first contains no ammonia, as such, (at least not in a state to be disengaged by lime or the alkalies, as is the case with all the known ammoniacal mixtures) yet when it has been brought by oxymuriatic acid to that point at which it precipitates a *green* prussiat of iron instead of a blue, and fixed alkalies or lime are added, it *now* gives the volatile alkali in abundance, and loses its peculiar peach flower smell. At the same time it effervesces with the stronger acids, and carbonic acid is disengaged. Hence it seems the most probable supposition that prussic acid contains neither carbonic acid nor ammonia ready formed, but the elements of these, (with the exception of oxygen) or in other words, that prussic acid is a combination of carbon with hydrogen and azot.

The method indicated by Scheele of composing prussic acid, by heating together ammonia and charcoal, was repeated by Clouet[a] in a different manner, that is, by passing ammoniacal vapour through red-hot charcoal. This vapour was disengaged from a mixture of lime and sal-ammoniac in an earthen retort, the neck of which was luted into a porcelain tube containing charcoal, and lying across a small furnace. To the opposite end of the tube was luted a tubulated balloon, which communicated

[a] An. Chim. tom. xi.

with two other balloons in succession, the first of which contained a solution of sulphat of iron, the second, some of the same solution acidulated, and the third, an acid nitrous solution of iron. When the charcoal was red-hot, the ammonia was passed through it, and the gas in passing through the three balloons, produced a large quantity of Prussian blue in the first (which contained neutral sulphat of iron) but none in the second or in the third. In another experiment the first balloon was filled before the operation with sulphuric acid, largely diluted with water, the second contained distilled water, and the third, caustic soda in dilute solution. When the operation was finished, the first balloon contained sulphat of ammonia (owing to the passage of some undecomposed ammonia) and also some prussic acid, so as to give the blue prussiat on adding a solution of iron. The second appeared to hold pure prussic acid, and gave Prussian blue on adding a solution of iron, and along with it some alkali. In the third, the soda was found combined with a large quantity of prussic acid.

This experiment was repeated by Bonjour,[b] who on adding potash and oxyd of iron to one of the balloons, obtained in it after the distillation a sensible quantity of crystallized prussiat of potash.

The prussic acid often makes its appearance (and is detected either by the peach-flower smell or by the blue precipitate which it forms with solutions of iron) during a variety of decomposing operations on animal substances either spontaneous or artificial. Thus Vauquelin found it produced by the action of nitric acid on serum, and Fourcroy and others have detected it as an occasional product (though rare) of animal putrefaction.

This acid is also contained in the vegetable kingdom in small quantity, in those substances where the smell would indicate it to be, that is, in bitter almonds, peach flowers, in the leaves of the lauro-cerasus, &c. As these contain a poisonous principle, it has been conjectured with some probability that it may reside in the prussic acid, which is itself highly deleterious.

M. Schrader[c] detected this acid in these vegetable substances by adding lime to the concentrated infusion or distilled water, then applying a solution of iron and acid. Vauquelin also[d] obtained a notable quantity of the acid in the distilled water from the kernels of apricots, and that of bitter almonds. These waters were mixed with a solution of iron, then precipitated entirely by ammonia, and after stirring the mixture and repose for some hours, sulphuric acid was added, which dissolved the excess of oxyd of iron, and left an insoluble blue-green precipitate, which retained its colour for some days, but immediately became blue in the heat of boiling water. The alkalies took away the blue colour and changed it to yellow, as they do the common blue prussiat of iron. As the heat employed here was not superior to that of boiling water, it appears more than probable that the prussic acid was merely expelled from the almond and other kernels by distillation, and not formed in the process, which therefore will entitle the prussic acid to be considered as one of the immediate vegetable principles.

Prussiats. We shall now describe more fully the more important combinations of this acid with the various bases.

Prussiat of Iron. This salt cannot be made by the direct combination of the prussic acid and iron, but is always the result of the decomposition of the solution of iron in another acid. When the pure prussic acid is added to any solution of this metal, the prussiat of iron thus formed is at first green, and is soluble in acids, hence much of it, and often the whole, remains in the solution, and no precipitate occurs. But on exposure to the rays of light, or to sulphureous acid, or if metallic iron is added to the solution, the colour becomes blue, and the prussiat, which is now no longer soluble in acids, falls down. Hence it would appear that pure *blue prussiat of iron* (which may be distinguished from *Prussian blue* by containing nothing but prussic acid and oxyd of iron) contains the metal in a less oxygenated state than in the green solution.

Another simple prussiat of iron has been noticed by Berthollet. When an alkali is digested with blue prussiat, a division of its constituent parts takes place;[e] the alkali dissolves out the greater part of the prussic acid, and a smaller part of the oxyd of iron, and these three substances, when the solution is evaporated, unite to form that triple salt, the *prussiat of potash with iron*, which is commonly termed simply *prussiat of potash*, and which will be presently described. The remaining and insoluble part of the blue prussiat, now consists of prussic acid, with an excess of oxyd of iron, and is of a yellow colour bordering on red. It may be termed with propriety the *sub-prussiat of iron*, but though it

[b] Journ. de l'Ecole Polytechnique 3d Cahier. [c] Journ. de Phys. tom 56. [d] Ann. Chim. tom. 45. [e] Mem. de l'Acad. 1787.

always contains more oxyd, or (what is the ſame thing) leſs acid than the blue pruſſiat, the preciſe proportion of its conſtituent parts is found to vary conſiderably, whereas thoſe of the blue pruſſiat are much more conſtant. When any acid is poured on this ſub-pruſſiat, it diſſolves the exceſs of oxyd, and immediately brings it to the ſtate of blue pruſſiat, which again may be decompoſed by alkalies as at firſt, and another but ſmaller quantity of ſub-pruſſiat is left; and thus by ſucceſſive applications of acid and alkali the whole may be decompoſed.

It has been mentioned that a blue pruſſiat may be made, ſimply by adding pruſſic acid to a ſolution of iron, and expoſure to light. This therefore can contain nothing but pruſſic acid and oxyd of iron, probably in proportions which vary but little, if at all. But when that pruſſiat is prepared in the uſual way, by adding pruſſiat of potaſh to the ſulphat or any other ſalt of iron, the blue precipitate always carries down with it a portion of alkali, with which it firmly unites, ſo as to render the alkali inſoluble in acids or in water. Hence it is that though the actual quantity of alkali in the pruſſiat of potaſh is more than ſufficient to ſaturate the acid of the iron ſolution, the latter always remains acidulous after the blue precipitate has ſubſided.[f] This will explain the great weight of ſuch precipitates compared with the quantity of metallic oxyd contained in the ſolution which has been decompoſed.

Beſides the ſpecies of pruſſiats of iron already mentioned, that is, the blue and the yellow, or ſub-pruſſiat, which differ in the proportions of oxyd of iron which they contain, another is deſcribed by Prouſt, the *white pruſſiat*, which is ſtated to have the ſame proportion of acid and iron as the blue pruſſiat, but in which the metal is in a much lower ſtate of oxydation. The method of procuring the white pruſſiat is the following:[g] take a ſolution of *green* ſulphat of iron, or that in which the metal is at the loweſt ſtate of oxydation (and which is prepared from the common ſulphat by adding iron filings, or tin, or ſulphuretted hydrogen, and has been deſcribed under the article Iron) add to it a ſolution of pure pruſſiat of potaſh, rather more than is ſufficient to decompoſe it, and cork the bottle immediately. A copious white precipitate falls down, which is the white pruſſiat of iron, and ſoon becomes green, but if the bottle remains corked this colour does not deepen, nor alter by expoſure to light. After ſtanding for ſome hours, it becomes covered by a yellow liquid, which is a mixture of pruſſiat and ſulphat of potaſh, together with a little of the white pruſſiat, which is held in ſolution, and hence if expoſed to the air it becomes blue, and a blue pruſſiat is precipitated.

The white pruſſiat therefore, according to this ingenious chemiſt, differs from the blue only in containing leſs oxygen, which it has a very ſtrong tendency to abſorb from the air, or from all bodies that yield this ſubſtance, and thus to paſs into the ſtate of blue pruſſiat. Thus the oxymuriatic acid effects this change immediately, the nitric acid more ſlowly. But the ſulphuric and muriatic acids have no effect. On the other hand, the de-oxygenating ſubſtances, ſuch as ſulphuretted hydrogen, have no effect on the white pruſſiat, but bring to this ſtate the blue pruſſiat when long kept in contact with it. The ſame change is produced when the blue pruſſiat is kept in water in a well-cloſed bottle, in contact with bits of iron or tin. Conformably with his theory concerning the ſalts of iron, Prouſt concludes therefore, that in the white pruſſiat the metal contains 27 *per cent.* of oxygen; in the blue, when fully oxygenated, it contains 48 *per cent.* and he ſuppoſes that there is no intermediate ſtate of oxygenation, except what may be produced by the mere mechanical mixture of one oxyd with another in any given maſs.

This however he ſuppoſes is actually the caſe for the moſt part with the white pruſſiat, that is to ſay, it ſcarcely ever can be obtained, or at leaſt preſerved, for any time perfectly white, but from the preſence of atmoſpherical air, or other ſources of oxygen, a ſmall and varying portion is always converted into the blue oxyd, and in mingling with the whole maſs, it gives thoſe different ſhades of blue-green which are obſerved.

Such is the theory given by Prouſt of the difference between theſe two pruſſiats, which however is called in queſtion by Berthollet,[h] on account of the great rapidity with which the blue pruſſiat is formed in various circumſtances where the operation of the external air can hardly be ſuppoſed to act. The facts given by Berthollet are the following: if a mixture of the green or leaſt oxydated ſulphat of iron be mixed with pruſſiat of potaſh, though the latter is in large proportion, the liquor retains the vitriolic taſte, ſhewing that the whole of the ſulphat of iron is not decompoſed, and the ſubſtance which Prouſt calls the white pruſſiat is precipitated; but if diſtilled water is added to

[f] Berthollet, Chem. Statics. [g] Ann. Chim. tom. 23. [h] Chem. Statics.

the mixture it immediately becomes of a deep blue, with a greeniſh tinge. Muriatic acid gives it a deep blue colour, and ſo ſpeedily, that no ſenſible action of the atmoſpheric air can be ſuſpected.

Again, if ſome of the white pruſſiat be put into a flaſk filled with muriatic acid, and inſtantly corked, it becomes perfectly blue, and the ſame takes place with the ſulphureous and phoſphoreous acids. Alſo if white pruſſiat be formed in a glaſs, and ſulphuric acid poured down upon it, the whole becomes blue that is in the reach of the acid, whilſt the liquor at top remains colourleſs. Theſe three laſt experiments are directly in contradiction to Prouſt, who aſſerts that the acids which do not impart oxygen, ſuch as the ſulphuric and muriatic, do not change the white pruſſiat. Berthollet explains theſe phenomena in the following way: in experiments on the metallic ſolutions it is found that the oxyd of iron adheres much more ſtrongly to the ſulphuric acid when it is a little oxydated than when it is much ſo; therefore the *green* ſulphat is not decompoſed by pruſſiat of potaſh when both ſolutions are concentrated, but yet theſe two ſubſtances exerciſe a mutual action which ſimply ſeparates them from the ſmall quantity of water which they contain. If however this quantity is increaſed, the action of the ſulphuric acid on the oxyd is proportionably leſſened, and *then* the pruſſic acid begins to combine with the iron and produce the blue pruſſiat, which mixes with the white compound and colours it, but as the pruſſiat has an exceſs of oxyd of iron, the colour is greeniſh. Hence is explained the effect of ſimple dilution with water on the white maſs, which Prouſt ſuppoſes to ariſe from the atmoſpheric air that the water may contain. If beſides, an acid is added (of whatever kind it be, whether ſuch as is liable to yield oxygen, or to abſorb it) this combines with the alkali preſent in the white maſs, and thus increaſes the action of the pruſſic acid on the oxyd of iron, and enables it to decompoſe the ſulphat. This alſo is ſtill farther augmented, if the acid alſo imparts oxygen to the oxyd, inaſmuch as by ſo doing, it weakens the affinity between the oxyd and ſulphuric acid, and renders it more eaſily decompoſed by the pruſſic acid. Berthollet however acknowledges that there is ſome difference between the blue pruſſiats, according to their ſtate of oxydation, which gives different ſhades of blue, but he denies the exiſtence of the white pruſſiat as deſcribed by Prouſt.

From all that has hitherto been obſerved therefore we cannot reckon with certainty more than three pruſſiats of iron, viz. the green, blue, and yellow. In the two firſt the proportion of metal to pruſſic acid appears to be the ſame, but the green is the moſt oxydated, and is ſoluble in acids. The blue pruſſiat, which is the moſt known and the moſt intereſting, is inſoluble in water or in acids, but may be decompoſed by alkalies, and in the proceſs the *yellow* or *ſub-pruſſiat* is left, which contains an exceſs of metallic oxyd, probably in the ſame degree of oxydation as in the blue pruſſiat, and may be brought to the blue ſtate by any acid which ſimply diſſolves the exceſs of oxyd. Theſe pruſſiats however, and particularly the blue, are in general triple ſalts, owing to a ſmall quantity of alkali which they retain, but they muſt not on that account be confounded with the cryſtallized pruſſiat of potaſh and iron.

Pruſſiat of Mercury. The pruſſic acid exerciſes ſo ſtrong an action on the oxyd of mercury, that even corroſive muriat is decompoſed by Pruſſian blue, and all the oxyds of this metal do the ſame, as has been already obſerved when deſcribing the method of obtaining this acid pure. The pruſſiat of mercury duly evaporated cryſtallizes in tetrahedral priſms. It is the only ſimple combination of this acid and a metallic oxyd which will cryſtallize. When pruſſiated lime [i] (meaning the combination of pure pruſſic acid with lime, and not the triple ſalt formed by digeſting Pruſſian blue with lime, for this contains iron) is added to nitrated mercury, a *black* precipitate falls down, which is the mercury reduced, and therefore ſeparated from the pruſſic acid.

Pruſſiat of Silver. The pure pruſſic acid when added to nitrated ſilver, precipitates a white pruſſiat of ſilver. When this metal is previouſly ſeparated from its ſolution by carbonat of ſoda, this acid unites with it, and forms white pruſſiat as before, and expells the carbonic acid which it contains. If the pure pruſſiat of lime as above deſcribed is added to any ſolution of ſilver, it forms a white curdy precipitate. [k] If more of the liquor is added, the precipitate rediſſolves, and this ſolution cannot then be decompoſed by muriatic acid or muriat of ammonia, which is a ſingular anomaly. The precipitate itſelf is inſoluble in acids.

Pruſſiat of Copper. The pure pruſſic acid digeſted with the carbonated oxyd of copper efferveſces and turns it of a faint lemon colour,

[i] Scheele. [k] Ibid.

but it does not alter the solutions of this metal. If the pure prussiat of lime is added to the sulphat of copper it first precipitates a lemon-coloured prussiat of copper, which more of the liquor redissolves, and this solution is soluble in ammonia without turning it blue. If more of the sulphat of copper is added, the precipitate likewise disappears.

Some acids dissolve only a portion of this precipitate, and the remainder is white, but the muriatic acid dissolves the whole.

The triple prussiats also, whether with an alkaline or earthy basis, decompose compleatly all solutions of copper, and with more ease than the simple prussiat, as indeed is the case with all the other metallic solutions. The prussiat of copper thus prepared is of a beautiful bright-brown, which mixes well with oil, and in beauty and intensity surpasses every brown paint now in use. It has been introduced into the arts by Mr. Hatchett.[1] He prefers the muriat of copper precipitated by prussiat of lime. It must be well washed with cold water after precipitation, and dried without heat.

This salt is however in fact a prussiat of copper and iron, for this acid appears to carry with it in all its combinations, except that of mercury, a certain, and even considerable, portion of oxyd of iron. As a proof of this, when this prussiat of copper is digested with an alkali, the triple *prussiat of potash and iron* is obtained, as will be presently mentioned.

The other metallic prussiats are formed in a similar way with the above, but are of little importance.

Prussiated Alkalies and Earths.

Of these by far the most important is the

Prussiat of potash. It has been already mentioned that though the *pure* prussic acid is capable of uniting with caustic potash to saturation, the affinity between the two is extremely weak, so that this acid is displaced even by the carbonic, hence when this solution is exposed to the air, the alkali absorbs carbonic acid, and the prussic is expelled and evaporates. But when a certain quantity of oxyd of iron is present the effect is very different, and a triple salt separable by crystallization is formed, containing prussic acid, potash, and iron, to which the acid now adheres so strongly, that no acid can expell it unless heat is employed, except the oxymuriatic, which decomposes and destroys the prussic acid. This triple combination of prussic acid, oxyd of iron, and potash, is usually termed simply *prussiat of potash*, which we shall here retain.

A great many experiments have been made by chemists to prepare this salt pure and of uniform composition, as in this state it is a valuable chemical test, having the property of forming a precipitate with all the metallic solutions except those of gold, platina, and antimony, but with none of the earthy solutions except muriat of alumine. Thus the same test duly applied will tell the presence of any metallic salt (with the exceptions above mentioned) and by the colour of the precipitate two or three of the individual metals may be discovered, particularly iron and copper; and where iron alone is present, the quantity may be found by drying, weighing, and igniting the precipitate, deducting from the residue the proportion of iron essential to the prussiat added. On account however of the great difficulty of preparing an alkaline prussiat with an uniform proportion of iron, this test is seldom employed to ascertain the *quantity* of iron in any solution, but only its presence.

Two or three good methods have been given for preparing prussiat of potash. They are all essentially the same, and are founded on the following principles: when an alkali is digested with heat, upon Prussian blue, a great part of the acid, and a small part of the oxyd of iron of the blue, unite in solution with the alkali, and a yellow prussiat of iron with excess of oxyd is left, as has already been mentioned. It would seem therefore at first that no more was required to prepare the prussiat of potash, than to evaporate the solution to the proper point and to crystallize. This indeed, if the alkali were saturated, would readily afford the crystals required; but in this state if any acid is poured on them, a copious separation of blue prussiat will take place, and therefore it would lead to great errors in analysis, as an indication of iron will be given in the liquor examined by this test, when it merely contained an excess of acid. The reason of the effect of acids on this unpurified prussiat of potash in precipitating blue prussiat, seems to be, that during the first digestion of the alkaline ley and Prussian blue, a considerable portion of the sub-prussiat of iron, of the same nature as that left behind, is taken up (for this is found to yield a similar blue precipitate by the simple addition of an acid which dissolves the excess of iron) and hence it becomes necessary to purify the prussiat of potash from the

[1] Journ. Royal Inst. or Phil. Mag. vol. 4.

whole of this sub-prussiat before it can be depended on as a test.

The proportions of the constituent parts of pure prussiat of potash are not absolutely constant, but in general they may be stated to be those in which the alkali is perfectly saturated with the prussic acid, and contains the smallest possible quantity of oxyd of iron consistent with the nature of the salt. The latter is still very considerable, being from 22 to about 30 *per cent.* of the weight of the entire salt. It may be found in the following way: take a known quantity (100 grains for example) calcine it to moderate redness in a silver crucible, by which the prussic acid will burn off, and the potash and oxyd of iron be left. Wash the residue thoroughly with hot water to dissolve the alkali, filter, and collect the oxyd of iron left. But as this is in the lowest state of oxydation in the prussiat, calcine it for a short time in a covered crucible with wax, till it becomes magnetic, and then weigh it. When this exceeds about 30 *per cent.* of the prussiat employed, the latter generally deposits Prussian blue by the affusion of acids, and consequently is impure.

Another substance that is always found in impure prussiat is sulphat of potash, for it is scarcely possible to obtain any potash free from it without unusual care, and besides, the Prussian blue itself contains a little sulphuric acid obtained from the alum with which it is prepared. This acid may lead to error where the absence of a metal in any solution is to be inferred from the want of a precipitate on adding the prussiat, for if the latter contains any sulphuric acid it will decompose and precipitate the salts of barytes, and strontian, and (if in quantity) those of lime. The sulphuric acid must therefore be previously separated by a solution of barytes. It may be here remarked that the delicacy of this test is so great as to detect sulphuric acid in the most minute quantity; and as most of the common prussic solutions contain this acid, a precipitate is generally formed when a barytic solution is added, which was erroneously supposed to arise from the union of prussic acid with this earth, and this was brought in confirmation of the hypothesis of the *metallic* nature of barytes. This mistake was first detected by Mr. Meyer of Stettin,[m] which is of importance, as it allows us to use barytes to separate the sulphuric acid from the prussiat, without danger of decomposing the prussiat itself, unless too much be employed

Prussiat of potash may be prepared in the following way:

Procure a solution of very pure carbonat of potash, make it caustic or nearly so, by lime (in the way mentioned under the article *Potash*) put it into a glass flask, heat it nearly to boiling, and project in it some prussian blue finely powdered. The blue colour will be taken away almost immediately, and turned to brown, after which continue projecting more of the blue, till the portion last added no longer loses its colour. The lixivium is to be boiled for a quarter of an hour, and is then as much saturated as it can be in this way, and is to be poured off clear from the sediment, and the latter edulcorated. Then collect all the clear liquors, heat them and add a little sulphuric acid moderately diluted, and continue a moderate heat [n] for some time, after which a copious precipitate will be formed of prussian blue. Separate this by filtration, and assay a small portion of the liquor by sulphuric acid, and if any blue precipitate appears, add more of the acid to the whole liquor, which must again be heated for a time. When by assaying a portion no more blue precipitate is yielded, evaporate the liquor considerably in a gentle heat, and set it by to crystallize. In a day or two there will be found two sorts of crystals; one of them hard, pointed, and colourless, which is sulphat of potash: the other softer, yellowish, and generally cubical, which is prussiat of potash. Pick out these crystals (more of which may be obtained by further evaporation of the mother water) and redissove them in cold water, and add to the solution gradually some pure barytes dissolved in warm water, or acetited barytes, as long as any precipitate appears, and no longer. The solution also should be somewhat dilute, otherwise the precipitation will not stop at the point when only the sulphat of barytes ceases to be formed, but prussiat of barytes will then be produced, and being not very soluble, it will precipitate. Then again evaporate the filtered solution, and the prussiat of potash will now crystallize perfectly pure, and of a pale yellow colour. The purity of these crystals is known by their not assuming a blue colour when sprinkled with muriatic acid. If this test should fail they must be again dissolved, treated with acid, and the solution evaporated as before.[o]

Mr. Henry gives a process somewhat different, by which through the intermede of copper, the prussiat is still more effectually

[m] Phil. Journ. 4to. vol. iv. p. 30. [n] Henry's Epitome, 4to edit. [o] Klaproth in Kirwan's Mineralogy.

freed from superfluous oxyd of iron. It is, in a few words, the following: when the solution of prussiat of potash has been thoroughly purified by sulphuric acid, instead of evaporating it to crystallize, pour into it a solution of sulphat of copper in warm water as long as a reddish brown precipitate appears. Wash this prussiat of copper thoroughly, and add it by degrees to a solution of pure potash. The prussic acid then quits the copper and unites with the potash, still all along carrying with it a considerable portion of iron with which it finally crystallizes. Then test the solution with barytes, and evaporate and crystallize in the way already mentioned. The salt thus obtained is free from sulphuric acid and contains no more oxyd of iron than is absolutely necessary to its composition, and therefore none of the oxyd is unsaturated but is held in such firm union with both the prussic acid and potash as not to be detached by any simple affinity unless with the assistance of heat.

Prussiat of potash is a salt of a pale amber yellow colour, and easily soluble in four or five times its weight of water. The alkali is perfectly saturated, so that it does not alter vegetable colours. When the salt, either solid or in solution, is long heated or exposed to the light for some time it deposits blue prussiat of iron, and hence to keep it for chemical purposes it should be put into an opake bottle, or in a dark place. It is not very easy to explain precisely the cause of this change. Probably it is in the first instance produced by the dissipation of a portion of the prussic acid in the part immediately exposed to light, which leaves the remainder of this part in those proportions in which the blue prussiat is constituted; but as the latter contains scarcely any alkali, it is necessary that the corresponding portion of potash should also be detached from the part that has lost some of its acid before the blue prussiat can appear. What are the affinities that produce this effect?

The prussic acid will also unite to soda and ammonia by a similar process to that already described.

It is not absolutely necessary in forming any of the prussiated alkalies that the alkali should be in a caustic state, but it very much assists and shortens the operation.

Prussiat of Lime. When prussian blue is boiled with lime-water the same discoloration takes place as with potash, and the lime in saturating itself with the prussic acid becomes of a clear yellow colour. This liquor also deposits blue prussiat by exposure to light. It is an useful test for iron and copper, but on account of the lime it contains it is decomposed partially by sulphuric acid in many forms.

Prussiat of Barytes. This salt is formed in the following way, and has been examined particularly by Mr. W. Henry.[a] Make a solution of pure barytes in boiling water, and add by degrees pure prussian blue in fine powder (previously washed with hot water) till it ceases to be discoloured. Filter the solution, and after standing a few hours small yellowish crystals will appear, which are the prussiated barytes. From the remaining solution a further quantity of crystals may be obtained by evaporation. Their form appears to be a rhomboidal parallelopiped. This salt is very sparingly soluble in water, 4 oz. of which at 65° dissolve only one grain, and of boiling water 5 or 6 grains. It is totally soluble in dilute muriatic and nitric acid, and without decomposition. When heated to redness the prussic acid burns off, and the residue contains carbonat of barytes. Sulphuric acid, or any sulphat added to the solution of this salt decomposes it compleatly, and sulphat of barytes is precipitated. It is also decomposed by carbonat of potash, carbonated barytes falls down, and the solution contains prussiat of potash in great purity. This would be a short and unexceptionable way of preparing this latter salt, but very expensive. Prussiat of barytes may also be formed by the double decomposition of prussiat of potash and muriated barytes. When these salts are added together, if no sulphuric acid in any form be present, and the solution rather dilute, no immediate change in the transparency takes place; but after standing together for a few hours the bottom of the vessel becomes covered with minute crystals, which are prussiated barytes. It is this circumstance of some time being required to cause this precipitation that gives the opportunity of purifying prussiat of potash by barytic solution from sulphuric acid, without decomposing the prussiat of potash, as the sulphat of barytes falls down *immediately*, but the prussiat requires some time, so that the addition of the barytes should cease when the solution no longer gives an immediate precipitate. Barytic water added to prussiat of lime decomposes it and crystals of prussiated barytes gradually form.

Prussiat of Strontian.[a]

This salt is prepared like the former by digesting prussian blue with the pure earth. But this

[a] Phil. Journ. 4to. vol. 3 and 4. [b] Ditto.

prussiat does not readily cryftallize, and appears to be extremely soluble in water. It is not exactly determined, whether muriated or nitrated strontian decomposes prussiat of potash. Pure barytes added to prussiated strontian, causes a precipitate of prussiated barytes, but in very small quantity, so that it appears to decompose it only partially, and hence the affinity of barytes for this acid is not much stronger than that of strontian.

The affinities of the prussic acid are extremely difficult to be made out on account of the peculiar tendency which it has to form triple and even quadruple combinations. Among the metals, mercury appears to stand first and iron next, and among the earthy and alkaline bases the order is probably barytes, strontian, potash, and lime.

PUDDING STONE.

This term, invented by the English lapidaries, is applied by them to designate one particular mineral aggregate, consisting of oblong and rounded pebbles of flint, about the size of almonds, imbedded in a hard siliceous cement: the pebbles are usually black, and the cement is a light yellowish brown. It is capable of receiving a very high polish, and used to be much employed in inlaying and other ornamental works. It is chiefly procured from the county of Essex. Many of the French mineralogists have naturalized this term (Poudingue) and have applied it to all rounded stones imbedded in a cement, so as to make it nearly synonimous with the German *Agglomerat*, and the English *Rubble-stone*.

PUMICE. Bimstein, *Wern*. Pierre Ponce, *Br ch*.

The colour of this mineral is greyish white, bluish or yellowish grey, greyish black and reddish brown. It occurs in mass and disseminated, being always more or less cellular or carious. It is glistening, sometimes even shining, with a silky lustre. Its fracture is fibrous. Its fragments are indeterminate moderately sharp edged. It is opake, sometimes a little translucent on the edges. It is soft, that is, is readily scratched or pulverized, but its particles when in powder have a considerable hardness. It is brittle and very meagre to the touch. Sp. gr. 0.91.

It is fusible without addition before the blow pipe into a white enamel. It is composed according to Klaproth of

77.5	Silex
17.5	Alumine
1.75	Oxyd of Iron
96.75	
3.25	loss
100.	

It is generally looked upon as a volcanic product. It is wrought in considerable quarries in the Lipari islands, which are almost entirely composed of this mineral. It also occurs in Sicily and Iceland.

Pumice stone is extensively used for grinding down metals, glass, ivory, &c. previous to polishing; it is also employed for smoothing leather, and other similar purposes.

PUTREFACTION.

Putrefaction is that spontaneous process of decomposition which takes place in all the soft parts of animals, and some vegetables under proper circumstances of temperature and moisture, by which they are finally disorganized, and are chiefly resolved, when with access of air, into a variety of gaseous and volatile compounds, which mingle with the atmosphere.

The subject of putrefaction is still very obscure, that is to say, though we know the circumstances required for it, and many of the products, we are very far from possessing exact ideas concerning the mode in which the constituent parts of the animal body break up their former combinations, and form new ones altogether different.

Putrefaction is naturally a very slow process, and the insuperable disgust and loathing attending it seem to forbid a very minute enquiry into this important phenomenon of nature.

We shall only mention a few of the facts known concerning it. The circumstances requisite to the putrefaction of animal matter, are a temperature from about 40° to the highest natural heat, and a constant moisture in the substance putrefying. The operation of a freezing temperature in stopping putrefaction is well known, by the constant custom in cold countries of bringing victuals frozen to market, in which state they will keep for any length of time without any other preparation; by bodies of men or other animals remaining unaltered under ice for many weeks, and the like. On the other hand, a scorching heat also prevents putrefaction, which it does however, apparently, simply by expelling the moisture which is essential to the process, for by any inferior

degree of heat putrefaction is much promoted. For the same reason also substances putrefy much more slowly when exposed to a drying wind, than in a sheltered place.

The obvious phenomena of putrefaction are the following, in any animal matter kept at a pretty uniform temperature, in a place not much exposed to currents of air, the substance first becomes soft and flabby, or if it is already soft, as in the case of the coagulum of blood, it resolves itself into a dark fluid, the colour then changes to green or brown, and an unpleasant smell begins to issue from it. As the process advances the soft parts then melt down into a putrid pulpy mass, and the fluids become turbid, and the effluvia become excessively loathsome and sickening, and after a time, the parts swell and become puffy, and disengage the putrid gas in a slow but sensible effervescence. A foul and brown serum then sweats out from the pulpy mass, and about this time the effluvium is very sensibly ammoniacal as is apparent from its effects on the eyes and throat, and by forming a white vapour with muriatic acid gas. Things continue nearly in this state for a considerable time, during which a large part of the putrid substance is evaporated, and carried off in the putrid gas and dispersed in the atmosphere, after which the extreme fœtor subsides, and finally the process of putrefaction ceases, and leaves a kind of fat fœtid earthy matter.

Such is the regular process of putrefaction, as far as relates to the external circumstances, and obvious phenomena, but it may be observed, that some parts putrefy much more readily than others, and some scarcely at all. Perhaps the most putrescent substance that we know is the blood, which property it owes partly to its fluidity and partly to the large quantity of fibrin and uncondensed albumen, which it contains, and especially to the former. Animal parts also seem to be (ceteris paribus) more putrescent in proportion to the number of constituent parts which they contain. The substances absolutely or nearly imputrescible, are bone and *condensed* albumen, the latter such as it exists in cuticle, nail, hair, &c. which long remain unaltered in the midst of putrefying substances. Animal *oil* also putrefies with great difficulty, and hence the people that live in the most northern parts of America, the Eskimaux and others, preserve fish and meat to a certain degree from putrefaction by immersion in fish oil.

The gasses certainly known to be produced by putrefaction are carbonic acid, carburetted hydrogen, sulphuretted and phospuretted hydrogen, and ammonia, but either these or some of these must be considerably changed by the solution of the animal matter, or some compound not yet examined must be produced in that state of putrefaction where the gas evolved occasions such dreadful effects upon those that unfortunately fall in the way of it, even when diluted considerably with common air. This is said to be the case when the abdomen of a large animal is first burst after some days, or perhaps weeks of putrefaction; the gas from which causes instant fainting, and sometimes death, and even when the person exposed to it recovers the first shock, it leaves excessive debility and other alarming symptoms for a considerable time. The most deleterious gas that we know is, perhaps, carburetted hydrogen, but the effects of this as obtained by chemical means, are far short of those above mentioned, when equally diluted.

The generation of ammonia has been satisfactorily accounted for since the discovery of the constituent parts of the volatile alkali, by the new combination formed between the azot of the animal matter, and the hydrogen, of which latter there are many sources, and particularly that of the decomposition of water. As ammonia is always produced during putrefaction, it seems rational to suppose that one important purpose of the moisture necessary to the process is to afford, by its decomposition, the hydrogen of the volatile alkali.

The circumstances which tend to the generation of the nitrous acid, (which is an undoubted product of putrefaction) have been mentioned under the article *Nitrat of Potash*, but many more experiments must be made, and facts observed, before we can explain, why in certain cases the azot tends to unite with oxygen to form this acid, and in others with hydrogen to form ammonia.

That peculiar change which takes place in animal flesh, whereby it is converted into a spermaceti-like substance instead of undergoing the usual mode of putrid decomposition, has been mentioned under the article *Adipocire*.

PUTTY.

True putty is made by calcining an alloy of equal parts of tin and lead: a white powder is thus produced that is the base of most of the opake enamels, and is also used in the polishing of metals, stones, and glass.

The glaziers' putty, used by them for fastening panes of glass into sashes, was perhaps ori-

ginally composed of true putty and oil; but at present it is nothing but washed chalk or whiting mixed up with linseed oil; a sort of ductile paste is thus produced which becomes hard after a few days exposure to the air.

PUZZOLANA.

Puzzolana appears to be nothing else than volcanic ashes more or less compacted together. It occurs either white, red, or black, has a dull earthy fracture, and is easily frangible. It abounds in the vicinity of Vesuvius. The red variety is the proper puzzolana, the black and the white are called in Italy *lapillo* or *rapillo*. The ashes which overwhelmed Pompeia now form a vast bed of white puzzolana. It is employed in calcareous CEMENTS to which it gives the property of hardening under water.

PYRITES.

A name first given by the ancient naturalists to the native sulphuret of iron, because when struck against a piece of steel or other hard body, it gives out sparks of fire, and because when heated red hot the sulphur that it contains burns with a lambent blue flame. Modern mineralogists distinguish three species of pyrites, namely, the ferruginous, the cupreous, and the arsenical, of which the first is sulphuret of iron, the second sulphuret of copper, and the third is a compound of iron pyrites and arsenic. All these substances have a general similarity in their external appearance: their colour varies from yellowish white to gold yellow, and they have all a high metallic lustre. For further particulars see the ores of ARSENIC, COPPER, and IRON.

PYROLIGNEOUS ACID
PYROMUCOUS ACID
PYROTARTAREOUS ACID
} See ACETOUS ACID, *Empyreumatic*.

PYROMETER. (*Wedgewood's.*)

The range of the common mercurial thermometer extends no higher than the boiling point of this metal (that is about 600°) and even this is a very inaccurate measure of heat in its higher part on account of the very unequal expansion of mercury as it approaches boiling. But this point falls short of that of the lowest visible red-heat, and from this to the highest temperature that furnaces will produce, a vast range of heat is included, for which no tolerably accurate method of measurement existed till the year 1782,[a] when the late Mr. Wedgewood invented his pyrometer. Previous to this time chemists were in the habit of using very vague terms to express the heat employed in their operations, such as *red heat*, *full-red heat*, *white heat*, &c. and the means used for measuring it were too inaccurate for the experimental chemist, though sufficient for the manufacturer when aided by daily experience. These were generally the degree of fusibility shewn by refractory earthy mixtures, the length of time which the crucible could endure the heat employed, the reduction of metallic oxyds and the like. Another method which is actually employed in the potteries, and answers sufficiently well, is the shade of colour produced by the heat on a ring of clay worked up with a little oxyd of iron. This is a light brown, or flesh colour in the lower red heats, but gradually darkens to a deep chocolate, or almost to blackness as the fire reaches its utmost intensity. This mode however can hardly be applicable as a general standard of comparison, as the shades of colour are not very definable, and not readily described, besides other objections which might be raised.

Mr. Wedgewood, therefore, on examining this subject, which his business as a potter rendered peculiarly interesting, found a new and much more accurate measure of temperature in the gradual, and on the whole pretty uniform contraction, which clay undergoes in all heats from the faintest red to the most intense which can be produced. From examining with minute attention the habitudes of clay with water and fire, and from the event of many experiments Mr. W. gives the following as the general result of his observations.

When a solid lump of pure natural clay, (such as the finest Devonshire kind) is well kneaded with water, and exposed very gradually to an increasing heat, the first change that takes place is the shrinking produced by the simple evaporation of water. The purer the clay is the more water it takes to soften it, and therefore the more it diminishes in bulk by the loss of moisture. The clay dries at a heat below redness, and preserves its bulk unvaried up to the approach of ignition. At this period it *enlarges* a little, owing probably to the escape of air with which it has been combined.

When this air has made its escape, the clay begins to shrink and returns to precisely the same dimensions which it had before, when thoroughly dry. When thus prepared and brought to this point, it is fit to be used for the pyrometer, and forms the beginning or lowest point of the scale, which as above-mentioned is

[a] Phil. Trans. for 1782, 4, and 6.

the lowest heat of *ignition*, or that in which a body is just perceptibly red-hot in the day time. From this point it shrinks gradually and pretty uniformly in proportion as the heat is increased, till it reaches its utmost degree of contraction, (which varies according to the nature of the clay,) thus forming a range which may be used for thermometric purposes. In the purest natural clays it reaches nearly to the highest artificial heat procurable in furnaces, but in other clays, though to the eye equally pure, the contraction stops very short of this, and then a *second expansion* takes place.

At this time it is intensely hard, and has a texture approaching to the *vitreous*, so that the second enlargement appears to depend in part perhaps, on a further disengagement of gas, but chiefly probably on an alteration in its texture. During the first part of the pyrometric scale, (that is from low redness upwards) the clay continues bibulous and sticks to the tongue. This ceases however some time before the second expansion comes on, whence Mr. Wedgewood conjectures, that the *porcellanous* state (which is intermediate between the earthy and the vitreous) comes on when the clay ceases to be bibulous, and remains till the vitreous expansion begins. It may be observed, as before mentioned under the article *Alumine*, that the shrinking which takes place after ignition cannot be attributed to the evaporation of water or any other substance, for the loss of weight is much too small to allow of this explanation. The entire contraction, from ignition to the highest procurable furnace-heat, is full one-fourth of the bulk of the clay in every dimension, when it remains unvitrified at so high a temperature; but the loss of weight from ignition to the heat that melts copper, which is about a sixth of the entire contraction, is only 2 per cent. of the weight of the clay, and above this latter point no loss is perceptible by the balance.

It has been mentioned above that samples of clay though apparently equally pure and white, and even taken from the same bed, though sufficiently similar for most purposes of manufacture, do not undergo the same degree of shrinking in the fire; for some continue to contract at every procurable intensity, whereas others, above a certain point, again expand and assume a vitreous texture. Neither do the *first* expansions, which take place just at ignition, sufficiently correspond. This circumstance caused a good deal of embarrassment to the inventor, as after the first sample of pyrometer clay was exhausted, (which happened to be of the kind the most refractory in the fire) he could not be certain of obtaining another mass which would correspond with the former in contraction. This led him to examine the contraction of pure alumine precipitated from alum by an alkali (that is to say, as pure as it is usually obtained without extreme precaution and great expence, and therefore still retaining both sulphuric acid and potash) and he found that it continued to contract, and even remained bibulous so as hardly to become porcellanous, by the highest heat of a furnace. This prepared alumine when mixed in certain proportions with the natural clays also rendered them sufficiently unalterable in texture in the fire, and brought their contractions to correspond with those of the pyrometer-pieces already made. The alumine is prepared by precipitating a solution of alum with good pearlash, and washing it repeatedly with large quantities of boiling water. The precipitated earth when it is somewhat condensed by settling, is to be used in that gelatinous state undried, as it then mixes much more easily with the natural clay. Mr. W. found that a mass of ten hundred weight of the second clay which he employed required all the earth of five hundred weight of alum to bring it to the same state with the pyrometer-pieces already made. This prepared alumine is much more tenacious of water than common clay, so that the mixture requires a more careful drying and at a higher temperature, before the size of the pieces is adjusted, and this should be done immediately after giving them a boiling-water heat, as they again absorb some moisture from the air (owing doubtless to the potash contained in the alumine) which would make the difference of two or three degrees of the scale, if the adjustment was delayed till that time.

The pyrometer is actually made in the following manner. It consists of two parts, the clay-pieces and the brass gage. Each clay-piece is a section of a cylinder of clay about the thickness of the little finger, and the length about equal to the diameter. One side is a little flattened, that it may slide more accurately along the gage. This latter consists of a long canal formed by two perfectly straight bars of brass fixed on a plate of the same metal in a converging direction, and graduated into 240 equal parts, beginning at the widest extremity. The width of the canal at one end is to that at the other in the proportion of 5 to 3. The gage to be more portable, is cut in halves, which are placed side by side on the same plate.

The clay pieces are previously baked just to ignition, or to a red-heat barely visible in the day-time, and when applied to the gage they just reach the o. of the scale. Every increase of heat contracts the piece, which therefore can be slid further into the gage. The clay pieces will bear the most sudden heating and cooling without in the least cracking or splitting, and indeed their size is such that in two or three minutes that they have undergone the utmost effect of any particular degree of fire, so that no long continuance of the same heat is necessary. To employ this pyrometer one of the pieces must be put in or contiguous to the part where the heat is to be ascertained, inclosed if necessary in a very small crucible. If thrown on burning coals in a high heat it becomes somewhat rough on the outside and firmly covered with a kind of black enamel, which possibly may render it less accurate. It should also be kept from the immediate action of any saline or other fluxes which would corrode its surface and impair its accuracy, but in other respects it requires but little precaution. It is a peculiar property, and generally an advantage, of this pyrometer, that each clay-piece tells only the extremest heat to which it has ever been exposed, and never returns to any inferior point of the scale like all other thermometers, so that it may be gaged at any distance of time from the experiment. Even if the piece is broken or injured, if the compleat ring of the cylinder remains, of whatever breadth, it forms as accurate a measure as when entire.

The degrees of this pyrometer only begin at a considerably greater heat than the termination of the mercurial thermometer, and hence in order to render them at all comparable, it became necessary to connect the two by some intermediate scale. This Mr. Wedgewood effected by comparing the expansion of a silver gage in the intermediate degrees; and by experiments, which it is not necessary here to detail, he was able to connect the two scales in a tolerably satisfactory way; though the heats are so remote that very little advantage can ever be derived from this method. Mr. W. found that the mercurial range of temperature was so small compared with the pyrometrical, that a single degree of the clay pyrometer was equivalent to 130 degrees of Fahrenheit, and the o. of the pyrometer, which is a low red heat, he found to fall at about 1077° Fahr. supposing the mercurial scale could be continued so high, and with an uniform expansion of the mercury. Mr. W. has extended the scale of his pyrometer to 240 degrees; this is entirely arbitrary, but it probably is more than amply sufficient to include all possible production of heat, since the greatest intensity of furnaces has not been found to exceed about 180 of this scale. These 240 degrees are estimated from the above data to be equivalent to 31200 degrees of the mercurial thermometer, and as the o. of the former is equal to 1077° Fahr. the extreme of the pyrometer scale would correspond with 32277° Fahr. could this be continued as high. Hence too the whole distance between freezing and boiling water, or from 32° to 212° Fahr. is equivalent to no more than about half a degree of the pyrometer.

We shall now give the pyrometrical correspondences with some of the most easily observed stages of the higher heats as observed by the inventor and others.

Red heat fully visible in day-light	0
Enamelling heat for pottery	6
Brass melts at	21
Swedish copper melts at	27
Fine silver melts at	28
Fine gold melts at	32
Vitrefying (or highest) heat of a plate-glass furnace	124
Working heat of ditto	57
Welding heat of iron 120 to	132
Greatest heat of a common smith's forge	125
Cast iron melts at	130
Basalt melts at	100
Antient Etruscan ware begins to contract (and therefore was baked) at from 30 to	20
Ditto compleatly melts at	36
Delft ware baked at	40
Queen's pottery ware baked at	86
Stone ware baked at	102
Worcester china vitrefied at	94
Derby ditto ditto at	112
Chinese porcelain only softens at	120
Ditto sinks down into semi-fusion at	156
True stone Nankeen does not in the least alter at	156
Pyrometer pieces assume a porcellanous texture at	110
Greatest heat of the best constructed air furnace probably does not exceed about	180

It remains to mention some uncertainties that still attend the use of this instrument, and

the difficulty in adjusting a sufficiently accurate standard of comparison.

The inventor observes that a corresponding pyrometer may always be constructed by making for a gage a converging canal with the widths at the two ends in the proportion of 5 to 3, with the sides perfectly straight, and divided into 240 equal parts—and by procuring natural or artificial clay, pieces of which will just enter the gage at a low red-heat, will go to 27° by the heat at which copper melts, to about 90° by the welding heat of iron, and about 160 by the greatest heat of an air furnace, the clay pieces all the while remaining perfectly refractory.

But the great difficulty which the inventor himself seems to have had in preparing a second parcel of clay similar in these respects to that already employed is of itself sufficiently discouraging, nor are the points which he gives for the construction of the scale at all comparable in accuracy with those by which the common thermometers are graduated. The heat of boiling water and of melting ice are fixed points in which (with a few simple precautions) every one would agree, but it is not so with a red heat barely visible in day-light, and still less with the utmost power of a wind-furnace of given dimensions. Even the fusing point of copper is liable to some variations according to the purity of the metal, and that of cast-iron is still more variable on this account, so that though we may consider Mr. Wedgewood's scale as affording very useful approximations to the expressions of comparative heats, it does not approach the accuracy of the mercurial thermometer. Neither have we any means of ascertaining in the higher heats whether the contraction of clay is at all equable, that is, whether equal numbers on the pyrometrical scale express equal increments of heat, as they do pretty accurately with the mercurial thermometer.

The analysis of Mr. Wedgewood's pyrometer pieces as conducted by Scherer,[a] shews them to be made of a very pure natural clay composed of about 54 per cent. of alumine, and 44 of silex, with hardly a trace of any other ingredient. As the Devonshire clays contain a much less proportion of alumine than is here given, the above pieces were doubtless made, as indicated by Mr. Wedgewood, by adding to the natural clay a considerable portion of precipitated alumine.

But on the other hand, Gazeran[b] in his experiments on this subject found the best imitation of the Wedgewood pieces to be produced by a clay in which the alumine was to the silex as 34 to 43, and pieces made of this material corresponded very closely with the original Wedgewood pieces at the heat of 160°, and shewed no sign of vitrification at this high temperature.

This subject therefore, which is highly interesting to the chemist and manufacturer, requires further experiments.

PYROPE. See Garnet.

PYROPHORUS, Homberg's.

This preparation was first discovered by the chemist whose name it bears, as the residue of the distillation of fecal matter with alum and vitriol. Improvements with respect to the cleanliness of the process were soon introduced, and the following is now the common mode of preparing this substance.[a] Take three parts of Roman alum in powder, and one part of coarse brown sugar, mix them together and heat the mass over a common fire in an iron ladle or a shovel. By the first impression of the heat both the alum and sugar melt and mix intimately with each other; after a little time when most of the water is evaporated, the residue begins to foam and swell considerably, and to give out a pungent empyreumatic acid: it must now be stirred constantly with an iron spatula, taking care to detach it from the ladle in proportion as it dries, and to heat every part as uniformly as possible: when the last remains of clamminess are destroyed, and the spungy black matter that is left is quite friable, it must be transferred while hot into a mortar, and hastily reduced to a somewhat coarse powder. As soon as it is pulverized, a green glass vial of the capacity of about six ounces, (previously luted on the inside by rinsing it out with a weak solution of borax thickened with pipe clay to the consistence of cream) is to be nearly filled with it and then set up to the neck in a crucible filled with sand, its mouth being loosely stopped with a piece of charcoal. The crucible is now to be placed in a furnace, or even in an open fire, and raised gradually to a moderate red-heat. At first a dense white vapour will issue from the vial for nearly a quarter of an hour, and will then be succeeded by an inflammable gas, burning with a light blue flame: as soon as this makes its appearance, the heat is to be kept up at an uniform temperature for about 20 minutes longer, after which, the crucible with its contents being removed from the fire, and the

[a] An. Chim. tom. xxxi. p. 172.

[b] Ditto, tom. xxxvi.

[a] Beaumé Chim. exper. I. p. 338.

mouth of the vial being cloſed with a plug of paper, it is to be quickly cooled till the vial can be ſafely handled; the pyrophorus is then to be haſtily poured into a warm and perfectly dry ground-ſtoppered vial, in which it may be kept without injury for any length of time provided the acceſs of air is carefully avoided.

Another excellent method of preparing pyrophorus is the following.[b] Mix together three parts of Roman alum and one of flour, and heat the mixture to dryneſs in an iron pot, as deſcribed in the preceding paragraph: the black calcined maſs thus produced, is to be put into ounce phials of green glaſs, coated without and within with clay. The phials thus charged are to be lightly ſtopped with balls of tempered clay and then ſet up to their necks in ſand in an iron pot; charcoal powder is then to be ſtrewed on to the depth of half an inch, over which is to be placed an earthen cover, luted to the pot. The whole apparatus is now to be placed in a furnace and kept at a red-heat for an hour and a half: at the expiration of this period being taken out of the furnace and cooled quickly, it is to be unpacked, and the phials containing the pyrophorus are to be placed with their mouths inverted in mercury, in which ſituation the pyrophorus may be kept for many years without injury.

Pyrophorus is a light dry black powder, which when poured out in a little heap on any flat ſurface, and expoſed to the air, preſently gives out an odour of ſulphuretted hydrogen, and in about a minute becomes red-hot, and burns with a very light bluiſh flame till the whole of the carbonaceous and other inflammable matter is entirely conſumed, nothing being left but the white earthy baſe of the alum. Sometimes, either from a defect in the preparation, or from the air not having been entirely excluded from the phial in which it is contained, the pyrophorus when poured out undergoes no ſenſible change; when this happens, however, the combuſtion may often be brought about by breathing on the powder, and thus ſupplying it with the moiſture which ſeems to be the primary agent in this phenomenon. Pyrophorus when made according to the laſt mentioned manner is ſo very inflammable as to take fire as it is falling from the mouth of the phial. If poured into a jar of pure oxygen gas it forms a brilliant fiery ſhower; the oxygen is for the moſt part conſumed, and there remain in the jar ſulphureous acid and carbonic acid gaſſes: the pyrophorus alſo being conſumed, with the exception of its aluminous baſe.

The chemical changes that take place during the formation and decompoſition of pyrophorus, appear to be the following. Firſt, by being heated below redneſs in the open air the ingredients enter into fuſion, and thus mix accurately with each other, then the water of cryſtallization is driven off from the alum, and of the ſugar or flour little elſe than the charcoal eſcapes volatilization. Secondly, the red-heat to which it is expoſed in the phial, cauſes the ſulphuric acid of the alum and the charcoal of the ſugar to react on each other, by which part of the charcoal is driven off in the form of carbonic acid, and part of the ſulphuric acid eſcapes as ſulphureous acid: the blue flame that characteriſes the latter part of this proceſs is in all likelihood cauſed by the volatilization and combuſtion of a portion of ſulphur, more than is requiſite to ſaturate the potaſh of the alum. Thus the pyrophorus when prepared, conſiſts of alumine, charcoal, and ſulphuret of potaſh in intimate mixture. Thirdly, when this powder is expoſed to the air a rapid decompoſition both of the air itſelf and of the moiſture that it contains takes place, the oxygen of each being abſorbed by the ſulphuret, while a ſufficient quantity of heat is diſengaged to bring the charcoal and remainder of the ſulphur to a ſtate of actual inflammation.

PYROXENE. See Augite.

Q

QUARTATION.

A method of ſeparating gold from ſilver. See Assay of Gold; and Gold, p. 528.

QUARTZ. *Quartz*, Broch. *Quarz*, Wern. We ſhall ſubdivide this mineral into the five following ſubſpecies.

1 *Subſp.* Cryſtallized quartz. Rock cryſtal. Rock cryſtal often occurs perfectly tranſparent and colourleſs, it is alſo found reddiſh, yellowiſh and greeniſh white, pearl grey, ſmoke grey, greyiſh black, honey yellow, clove brown, yellowiſh and blackiſh brown, wine yellow, ochre yellow, hyacinth red, blood and brick red, reddiſh purple, apple green, leek green, and olive green. Its primitive form is a rhomboid approaching nearly to a cube. But though this figure may be obtained by mechanical diviſion of the priſmatic cryſtals, it has never yet been

[b] Higgin's Minutes, p. 271.

found native. The known varieties which it exhibits are the following.

1. The pyramidal dodecahedron, composed of two six sided pyramids joined base to base, the angle formed by the plane of one pyramid and the corresponding plane of the other is $=103°\ 20'$ and the angle formed by any two of the adjacent planes of the same pyramid is $=133°\ 40'$.

2. The preceding, with a strait hexahedral prism interposed between the two pyramids, the angle formed by any plane of the pyramids and the adjoining plane of the prism is $=141°\ 40'$.

3. The same as var. 2, with the alternate solid angles at the base of each pyramid replaced by small rhombic planes.

4. The same as var. 2, with all the solid angles at the base of each pyramid replaced by trapezoidal planes.

5. The same as var. 2, with the horizontal edges of the prism replaced by trapezoidal, almost parallelogramatic planes.

The size of the crystals varies from small to very large; some of the largest prisms are more than two feet in length, and weigh above 100 lbs. The planes of the prisms are transversely striated, but those of the terminating pyramids are smooth. The crystals are commonly brightly shining, both externally and internally, with a vitreous lustre. Its fracture is conchoidal, passing occasionally into obscurely foliated. The fragments are indeterminately angular, and very sharp-edged. The colourless or slightly coloured varieties are usually transparent, but those that are much loaded with iron ochre are often only translucent: when transparent it exhibits a double refraction.

Its hardness is superior to that of glass, and it gives vivid sparks when struck against a steel. It is brittle and easily frangible. Sp. gr. 2.65 when pure, but when deeply coloured by metallic oxyds it is considerably more.

When two crystals are rubbed together they afford a phosphorescent light, and exhale a peculiar odour. By exposure to the blowpipe this mineral undergoes no change, except that certain of its varieties lose their colour. Even a blowpipe charged with oxygen gas is wholly incapable, according to Lavoisier, of inducing the least sign of fusion. According to Ehrmann however, it melts into an enamel, but in this case the quartz was probably heated on charcoal from which it might acquire potash enough to serve as a flux.

The purple variety, called amethyst, is composed according to Rose, of

97.5	Silex
0.25	Alumine
0.5	Iron and a trace of manganese
98.25	

Several of the varieties of crystallized quartz are used as seal-stones and ornaments of various kinds, on account of their hardness, the exquisite polish that they are capable of receiving, and the pleasing tone of their colours. The most perfectly transparent and colourless is called by the lapidaries *rock crystal*, and besides being applied to various purposes of ornament, it is cut into spectacle glasses, which from their hardness are not so liable to be scratched as those which are made of flint glass. The reddish purple or violet coloured variety is called *Amethyst*, and is occasionally ranked among the gems: it must not however be confounded with the oriental amethyst, which is a true gem, being a variety of corundum. The pearl grey or pale blue variety is called false, or *water sapphire*. The yellow and smoke coloured varieties are called *false topaz*. The green varieties are not unfrequently mistaken for chrysolite.

The largest and most esteemed crystals of quartz come from Madagascar, also from the Alps, from Norway, and Scotland, where they occur lining cavities in granite. Amethyst is commonly found in geodes of agate, and is chiefly procured from Catalonia in Spain; from Bohemia, Saxony, Silesia and the Palatinate in Germany; from Hungary; from Auvergne in France, and the Uralian mountains near Catherinenburg in Russia. Quartz crystals also occur in most metallic veins both of ancient and recent formation in every kind of rock.

There is scarcely any crystallized mineral so liable as quartz to contain foreign substances; sometimes drops of water and bubbles of air may be observed in it, also fibres of amethyst, capillary crystals of schorl and ruthil, scales of chlorite, and dendritical iron ore, &c.

2 *Subsp.* Fibrous quartz.

Its colour is yellowish or greyish white, and sometimes pale amethyst. It occurs in mass: it has a faintly shining vitreous lustre: its fracture is thick and short fibrous, either parallel, diverging, or radiated: the radiated is composed of globular distinct concretions, two inches or more in diameter. It is translucent, sometimes semi-transparent. In its other characters it agrees with the preceeding subspecies.

It occurs in veins and lining cavities, in both which situations it is generally in immediate contact with the rock in which they are formed. The variety with globular distinct concretions has hitherto been found, we believe, only in Cornwall, where it constitutes the great dyke or cross course which passes entirely across that country from north to south, cutting through and altering the direction of the metallic veins of that rich district.

3 *Subsp.* Granular quartz.

Its colour is snow white, yellowish or greyish white. It occurs in mass and as a component part of certain granites. Its lustre varies from shining to glimmering. It occurs in granular distinct concretions, which are sometimes cemented together by an infiltration of quartz. When the concretions are very fine, the fracture is nearly compact; when the concretions are larger, the fracture is more or less splintery. Its fragments are indeterminately angular, blunt edged. It is translucent. In its other characters it agrees with the first subspecies.

The fine-grained with silvery mica and cream coloured felspar, composes a granite that occurs near Schihallion in the central highlands of Scotland: the larger grained forms large blocks in argillaceous schistus, and other primitive rocks in Shropshire. This latter becomes of a pure snow-white colour by calcination, and is largely employed in the manufacture of China-ware.

4 *Subsp.* Compact quartz.

Its colours are to the full as various as those of rock crystal. It occurs in mass, disseminated, in rounded fragments, also of particular shapes, such as globular, tubercular, specular, cellular, &c. It varies in lustre from shining to glimmering, the former is generally vitreous, the latter is for the most part greasy or pearly. Its fracture is coarse splintery passing into minute conchoidal. Its fragments are indeterminately angular, not very sharp-edged. It varies from translucent at the edges to semi-transparent. In other particulars it agrees with the first subspecies.

It occurs in every kind of rock, from the oldest to the most recent, forming an essential constituent of some, as granite and gneiss, and composing veins and beds in others: sometimes it is found in considerable blocks, but never forms entire mountains.

There are three varieties of compact quartz, which require to be described separately.

Var. 1. Prase.

Its colour is leek-green; it occurs in mass. Its lustre is glistening, between resinous and vitreous. It is translucent. It occurs at Brütenbrun in Saxony, in a mineral bed, and appears to be a very intimate mixture of quartz and actynolite.

Var. 2. Milk or rose quartz.

Its colour is pale rose, passing into reddish, greyish and yellowish white. It occurs in mass. It is glistening, with a greasy lustre. Its fracture is more or less conchoidal. It varies between semi-transparent and translucent. It is supposed to be quartz coloured by manganese. It is capable of a high polish, and is formed into various ornaments. It occurs in a large grained granite at Rabenstein in Bavaria, and is said also to have been found in Finland.

Var. 3. Aventurine.

Its colour is yellowish red, or grey, greenish, or blackish. When held in the light it appears to be filled with silvery and yellowish spangles that reflect the rays of light with great brilliance. These spangles have been taken by some mineralogists for mica, but according to others the appearance is produced only by the particular direction of its laminæ. It is susceptible of a good polish, and is used for seal-stones and other ornaments. The finest aventurines come from Spain.

QUICKLIME. See Lime.

QUICKSILVER. See Mercury.

QUINTESSENCE.

Properly, the fifth essence, or the result of five successive distillations. The term is at present obsolete; but was used by the old chemists to express the highest degree of rectification to which any substance can be brought.

R

RADICAL VINEGAR. See ACETOUS ACID.

RAGG. See BASALT.

REALGAR. See ARSENIC, Sulphuret of.

REALGAR, Native. See ARSENIC, ores of.

RECEIVER, or RECIPIENT. } Articles
RECIPIENT, Italian. } of chemical apparatus, for an account of which see the Appendix.

RECTIFICATION.

This term implies the repetition of the processes of distillation or sublimation, generally with a less degree of heat than at first, in order thereby to purify the substances which are the subjects of them from all foreign matters with which they may be mixed. Thus alcohol is rectified by redistilling it at a gentle heat, by which it is separated from the water and other impurities contained in common distilled spirits.

RED CHALK or REDDLE. See IRON, ores of, p. 587.

RED LEAD or MINIUM. See LEAD, oxyds of.

RED SCHORL. See TITANIUM, ores of.

REDUCTION.

Is the decomposition of a metallic oxyd so as to leave the metal in a state of greater or less purity, and exhibiting the lustre which is so eminently characteristic of metallic bodies. Reduction is for the most part effected by charcoal and a high temperature, either with or without the assistance of fluxes. For the various modes of reduction in actual practice, see the articles of the different metals.

REFINING GOLD AND SILVER.

For a particular account of the method of purifying these metals, see the articles ASSAY, GOLD and SILVER.

REFRACTORY.

A substance that is either incapable, or even very difficult of fusion, is said to be refractory, such are quartz, pure clay, platina, &c.

REFRIGERATORY.

An article of chemical apparatus, for a description of which see the Appendix.

REGULUS. *Konig*. Germ.

The term in its most extensive sense means a metal in the proper metallic state. Although a very convenient word, it is not much in use at present, being proscribed by the chemical neologists. By the old chemists it was chiefly used as a distinctive appellation in those cases where a metal and one of its ores happened to be called by the same name. Thus the grey sulphuret of antimony, was known by the name antimony, long before it was suspected to contain a peculiar metal, hence when this discovery took place, the metal was called *Regulus of antimony*, to distinguish it from the ore from which it was procured. For a similar reason the metals arsenic and cobalt were called Reguli of arsenic and cobalt.

RESIN. *Harze*. Germ.

This term is given to a very important class of vegetable substances of which there is a great variety of species, differing from each other in consistence, colour, smell, and in some degree in chemical composition.

The origin of all the resins is the same, that is, they exsude spontaneously, or are extracted by incisions made in the bark of the resinous trees, and most of them gradually harden by exposure to air. A further portion of the same resin may also be always extracted artificially from the tree that yields it, by chemical methods. Resin is also very generally met with in certain parts of vegetables, though its quantity is so small, or its combination with other constituent parts is so strong as not to appear in its proper form till extracted by chemical analysis. Thus the bark of the cinchona contains no inconsiderable quantity of resin though none appears to the eye on mere inspection, or (probably) could be extracted by incision through the living tree.

The chemical properties which are usually understood to characterize a resin, are the following: it is first softened and then melted by heat, and when kindled it burns readily with a strong and generally fragrant smell, with copious flame and smoke, and leaves scarcely any residue behind. It is insoluble in water and most watery liquids, and is not *easily* acted on by acids or alkalies, except they are concentrated, and the action assisted by heat or long digestion. But it readily and totally dissolves in alcohol, forming a clear, but coloured, solution from which by far the greater part of the resin is precipitated in a pulverulent form unaltered, by the addition of water, which immediately renders the solution opake and turbid. It is also soluble in sulphuric ether, and in the fixed and volatile oils, particularly the latter.

But though all resins agree in the qualities of

inflammability, insolubility in water, and solubility in alcohol, there are several other circumstances which have usually been employed to distinguish the classes of resins.

Balsams according to the antient sense of the word was certainly applied simply to those resins that always remained in a fluid or semin-fluid state, such as the Balsam of Capivi, of Mecca, of Canada, &c. and these appear to be resins holding a superabundance of essential oil, so that when distilled *per se* a vast quantity of oil arises, and a hard brittle resin is left behind if the heat employed is only moderate. Thus turpentine, which is a natural balsam, yields by distillation abundance of the essential oil of turpentine; and common rosin (which is a true resin) is left behind.

The term Balsam however has of late been injudiciously applied in the modern chemical nomenclature to those two or three species of resins that contain a notable quantity of *Benzoic acid*, as described under that article.

Gum resins are natural mixtures of a true resin with another substance apparently of the nature of gum and soluble in water. Hence if they are triturated with water, they remain suspended in it in pretty intimate mixture for a considerable time, forming an opake emulsive liquor. By standing, however, the resin subsides, and the liquor becomes clear, but it retains the flavour and smell of the gum resin, and leaves on evaporation a small quantity of brown extractive matter. Gum-ammoniac is an example of this kind. This distinction however is not very precise, and is more useful in pharmacy than in pure chemistry.

There are some substances evidently resinous in their nature and origin, but which have other peculiar properties that have caused them to be excluded from the list of resins.

Camphor is of this kind, which possesses some distinctive characters that have already been fully described under that article.

Caoutchouc, copal, and perhaps amber also, appear to belong strictly to the class of resins, but each has some points in which it differs materially from them.

We shall refer our readers to the articles *Varnish* and *Turpentine* for some of the most important individual resins, and in this place only notice some chemical properties common to the whole class.

All the resins sink in water. Most of them are without taste or only give a slight pungency when long chewed. When heated *per se* in a close vessel, they first give a considerable quantity of essential oil proportionate to the softness and approach to liquidity of the resin, after which, if the heat is raised, they yield an acidulous water, carburetted hydrogen, and carbonic acid, and a brilliant spongy coal is left. The resins burn readily in the air, with much flame and a very dense smoke, which latter carries with it a large quantity of very pure charcoal, that settles upon all the contiguous surfaces, covering them with a fine *lamp-black*. Much water is also generated during this combustion.

Resins unite by melting, with sulphur, and also with phosphorus though with difficulty.[a] It is generally asserted that neither alkalies nor acids have any action upon resin, neither inflaming nor oxydating them nor reducing them to a soap.[b] This however is found to be entirely a mistake, for many of the acids, and the fixed alkalies act very powerfully upon these substances, as has been shewn by Mr. Hatchett in his valuable analysis of gum lac,[c] and more lately in his experiments on the production of artificial tannin.[d] The former have been already mentioned under the article *lac*[c], and the latter we shall chiefly refer to *tannin*, but with a short notice in this place of that part of these highly curious researches which more immediately refers to the properties of resins.

Potash compleatly dissolves resin by long boiling, and carbonat of potash acts considerably upon it though much less perfectly. This solution is clear and of a saponaceous consistence, and will bear dilution with water without becoming turbid, but on the addition of an acid the whole of the resin separates.

If a metallic solution in acid be added to the alkaline solution of the resin, a curdy precipitate is formed, consisting of the resin united most intimately with the metallic oxyd, which bears a strong resemblance to the similar precipitates formed by adding a metallic solution to soap.

When strong nitric acid is digested with resin it is first converted into a pale orange-coloured porous brittle substance, after which a repeated abstraction of the acid at a boiling heat, converts the resin into a deep yellow viscid substance, soluble both in water and alcohol, into a clear liquor, in which most of the resinous properties are lost. Very long continued digestion in the acid without heat will produce the same effect. Nitrous gas is produced in abundance during each distillation, and the strength of the

[a] Fourcroy. [b] Ibid. [c] Phil. Trans. for 1804. [d] Ditto for 1805 and 6.

acid which comes over is diminished, which shews that this change depends chiefly, if not entirely upon the action of the oxygen of the decomposed acid. This deep yellow solution produces no effect on nitrat of lime thus shewing the absence of oxalic acid. With acetited lead it gives a copious yellow precipitate, and with a solution of isinglass or any other animal gelatin it produces a dense yellow precipitate, insoluble in boiling water; and resembling in every other property the precipitate produced by galls, catechu, and other native vegetable *tannins*. This last effect however is not produced unless the resin has been long and repeatedly treated with nitrous acid, whereas the resinous properties are lost at an earlier period of the action of this acid. On the other hand, if the resin has been previously charred to a slight degree either by heat or by sulphuric acid, the artificial tannin is produced much more speedily. Hence Mr. Hatchett supposes that this tanning substance is formed in consequence of part of the oxygen of the nitric acid combining with the hydrogen of the resin so as to produce water, and a proportionate quantity of carbon being thus denuded it is capable of yielding the tannin by the subsequent action of the acid. It should be added too, that the same substance is produced in much greater abundance by the action of nitric acid on charcoal alone, which thus may be made to yield more than its own weight of tannin.

It has been mentioned that no oxalic acid is formed by the action of the nitric acid on the pure resins, and this appears to be a very good characteristic mark of these bodies, since most other vegetab e principles yield it in greater or less abundance This is particularly the case with mucilage and extract of every kind, and hence the natural *Gum-resins* when treated with nitric acid afford a small quantity of oxalic acid, which may serve to distinguish them from the true resins. This production of oxalic acid appears absolutely to prevent the formation of the artificial tannin, so that none of the latter could be obtained from gum-arabic, tragacanth, and other mucilages. The presence of the benzoic acid also in some degree counteracts the formation of tannin, and hence less of it is produced from gum benzoin, and balsam of tolu, than from the simpler resins

When concentrated fulphuric acid is poured upon any of the solid resins reduced to fine powder, it dissolves them in a few minutes and forms a transparent yellowish brown solution of the consistency of a viscid oil. This process seems at first to be a simple solution, but in a little time (especially if warmth be used) the colour of the solution progressively deepens, sulphureous acid gas exhales, and at length the whole becomes a thick fluid, of an inky blackness. A similar effect is produced by the action of this acid upon the liquid resins. If the acid is poured on common turpentine it dissolves it almost immediately, and if a portion of this solution be poured into cold water, the turpentine is precipitated in a solid brittle state like common yellow rosin. But if a second portion is thus decomposed after the interval of an hour or two the precipitated resin is of a dark brown; and a third portion after the interval of four or five hours is quite black. If the digestion be continued for several days, the production of sulphureous gas ceases, and the turpentine (or whatever resin be used) is converted into a black porous coal, which yields no resin to alcohol, and amounts in general to from a third and more to a fifth of the resin employed. The quantity of coal produced by sulphuric acid far exceeds that which is afforded by the simple application of heat, since these resins when heated strongly *per se* in close vessels leave behind scarcely a hundreth of their weight of coal. If separate portions of the resin procured by dropping the sulphuric solution in water after different periods of digestion are merely dissolved in nitric acid, the artificial tannin is only found in those solutions in which the resin is actually or nearly charred. The coal obtained from the resin by means of sulphuric acid is not only in much greater quantity than that produced by simple heat, but differs from it considerably in texture and appearance, being when obtained by the humid process, shining, hard, and sometimes iridescent; whereas that produced by calcining the same resins in close vessels is spongy and light. The former kind burns like some of the mineral coals with great difficulty, but the latter like common charcoal. The great difference in the proportional quantity of coal, is shewn by the following statement: 100 grs. of common resin afford by sulphuric acid 43 of coal, of which after exposure to a red heat 30 still remain, but the same quantity yields by calcination in close vessels only $\frac{1}{4}$ of a grain.

100 grains of mastich afford 66 grs. of coal, by the first process, but only $4\frac{1}{2}$ by the second.

100 grains of amber yield 56 grs. of coal by sulphuric acid, but only $3\frac{1}{2}$ by calcination.

On the other hand the difference between these respective quantities of coal from the mucilages is much less.

The acetic acid dissolves the true resins even without heat when digested with them for a considerable time, and on the addition of water the whole is again separated, apparently unchanged. This latter method is useful in analysis to separate resin and gluten, both of which are soluble in acetic acid, but the latter remains in solution when water is added. As the acetic acid does not (like the sulphuric and nitric) alter the resin, it affords a very useful re-agent in chemical analysis.

A very strong resemblance exists between the resins and the essential oils in many of their most important properties, whence some chemists have been disposed to consider these oils as the origin of resins. When an essential oil is exposed to the air, much of it is entirely evaporated, but the portion which is left gradually thickens, water appears on the surface, and the oil loses its volatility, and with it much of its smell, and gradually approaches to the state of resin. This change has already been mentioned under the article OIL *Essential* (page 183) and also the method of restoring a part of this oil by means of sulphuric ether into its original state, and the perfect resinification of the remainder.

Nitric acid also converts the essential oils into a resin, where the mutual action of the two substances (which is very rapid and intense) is moderated by dilution, or very gradual affusion of the acid in small quantities. This change (which is also mentioned in the same article, p. 184) takes place very remarkably with oil of amber, which resembles the essential oils in many properties. If about its own bulk of fuming nitrous acid is poured on it gradually, much heat is excited, and nitrous gas is given out, though the action is altogether less than with the essential oils, and in some hours the whole is resolved into a yellow acid liquor, weak of acid compared to the quantity employed, on which swims a tough yellow resin intensely bitter, aromatic, insoluble in water, but which dissolves in alcohol, and is precipitated from it by water. This singular substance leaves a musky smell when a little of its solution is suffered to dry in the air, and it has been introduced into medicine under the name of *Artificial Musk*.

We may conclude this article by a short enumeration of the most important of the true resins, the gum resins, and the substances, not prepared by art, to which a resinous nature has been usually attributed.[a] To attempt to enumerate them all would be endless, as there are few plants from which a species of resin may not be extracted by art, and even the number of those that exsude spontaneously is extremely great.

Though no classification will correctly correspond with their chemical properties, the limits between the resins and gum-resins not being very precise, we may usefully arrange the greater part of these substances under the head of *Liquid Resins or Balsams, Solid Resins, and Gum Resins*. The two first classes are entirely or almost entirely insoluble in water, except they contain benzoic acid, but totally yield to alcohol. Distillation with water extracts from the liquid resins a large quantity of essential oil, and leaves a residue much resembling the solid resins. The gum-resins are partly soluble in water and partly in alcohol.

LIQUID RESINS.

1. *Turpentines*. Under this name we may include all the liquid resins exsuding from the different species of pine, which from their importance in the arts and the immense consumption of them will be separately described under the article *Turpentine*. They all yield abundance of the limpid essential oil of turpentine when distilled, and by different modes of preparation furnish several varieties of *rosin, pitch, tar*, &c. There are at least four species of turpentines commonly known in the shops, the *Chio, Venice*, and *Common Turpentine*, and the *Canada Balsam*.

2. *Balsam of Capivi or Copaiba* is a clear yellowish resinous juice, about the consistence of thin treacle, which flows in considerable quantity from incisions made in the bark of a large tree of South America, the *Copaifera Officinalis*. This balsam has a very agreeable smell and a pungent bitterish taste. It grows stiffer by long keeping but never concretes into a solid. It dissolves totally in alcohol. When distilled with water it yields nearly half its weight of essential oil, and a brittle inodorous resin is left. It appears therefore to be a natural combination, simply of resin and essential oil.

3. *Balsam of Mecca, Opobalsam, or Balsam of Gilead*. This is a liquid resin which exsudes from the *Amyris Opobalsamum*, a small evergreen tree that grows in many parts of the Levant, and also in great perfection on the shores of the Red Sea. It bears an extremely high price among the Turks, who employ it chiefly as a cosmetic, and it is scarcely ever found genuine in any other part of Europe.

It is moderately fluid, of a yellowish white

[a] Murray Apparatus Medicam. Lewis Materia Med. &c. &c.

colour, very fragrant, and of a slightly bitter and acrid taste. Its chemical properties closely resemble those of the last mentioned species, and it is only mentioned in this place on account of the extravagant value which the Turks set upon it, which is far beyond that of all the other aromatics.

4. *Balsam of Peru.* This is a dark brown balsam of the consistence of thin honey obtained from the *Myroxylon Peruiferum* (as it is said) by boiling the twigs and bark in water, and when cold, the balsam swims at the top of the liquor and is skimmed off. There appears to be two species of this balsam, the *white* and the *brown*, but the latter is the only one commonly known.

This juice has a very fragrant smell and pungent taste. It is entirely immiscible with water and with the fixed oils, but dissolves in the essential oils and in alcohol. When this balsam has long remained at rest in any vessel, it deposits crystals, from which the benzoic acid may be obtained by sublimation.

By distillation with water this balsam yields $\frac{1}{16}$ of its weight of an essential oil, of a reddish colour, and a pungent taste. This oil probably also contains benzoic acid. When compleatly charred by sulphuric acid, Mr. Hatchett found 100 grs. to yield 64 grs. of mere charcoal. A compound tincture of this balsam forms the common *Friar's Balsam*, used as an application in cuts and slight wounds.

5. *Balsam of Tolu.* This juice flows from incisions made in the trunk of the *Toluifera Balsamum*, a large tree resembling the pine, which abounds in the province of Tolu, in South America. It is of a yellowish brown colour, and, when fresh, of a thick tenacious consistence, but by age it hardens so as to be moderately brittle in cold weather.

This balsam has a most fragrant smell, more so than most of the resins, somewhat resembling lemons. When chewed it clings to the teeth, and at first gives very little taste, but after a time it leaves an agreeable pungency in the mouth. When kindled it burns with a copious flame and smoke (like all the other resins) but this is accompanied with a very pungent fragrant vapour which excites coughing, and is owing to the volatilization of the benzoic acid that this balsam contains in some abundance, though in much less proportion than the gum benzoin. When this balsam is boiled with water it melts, and settles at the bottom of the vessel, and appears to remain there unaltered, but the water without losing its transparency becomes highly fragrant and pungent, and contains a notable quantity of benzoic acid. This acid may also be procured from it by the same methods by which it is extracted from the gum Benzoin, as described under that article.

Balsam of Tolu is totally soluble in alcohol, and it is entirely separated from this menstruum (the benzoic acid excepted) by water. If the solution is not too concentrated this precipitated balsam remains for a time suspended in the liquor and gives it a milky appearance. By distillation this balsam yields an essential oil and benzoic acid. A hundred grains of the balsam charred by sulphuric acid, gave fifty-four grains of charcoal.

6. *Liquidambar*, or *Liquid Storax.* This is a resinous juice, which flows from the trunk of the *Liquidambar Styraciflua*, a tree resembling the maple, found in Virginia and Mexico. This balsam is of the consistence of honey, reddish brown, nearly transparent, of an acrid unctuous taste and a fragrant smell. It is seldom seen, and has not been much examined.

Solid Resins.

7. *Gum Anime.* This resin, which is very rarely met with, exsudes from the trunk of the *Hymenæa Courbaril*, a large tree growing in Brazil and New Spain. It is brought over either in small roundish tears, or in larger masses, with the surfaces covered with a white powder. The colour is yellowish white and pellucid, it is very brittle, and gives a shining fracture. It resembles copal in appearance, but is readily distinguishable from it (among other things) by being easily and totally soluble in alcohol, which copal is not, without much difficulty and particular management. This resin has very little taste. It is insoluble in water, but forms a grateful yellow tincture with alcohol, which has a bitterish pungent taste. Distilled with water it gives a very small quantity of essential oil. The natives of the countries whence it is procured chew it, but it is never used in Europe.

8. *Benzoin.* This resin, which contains more of the benzoic acid than any other substance, has already been described under this article.

9. *Dragon's Blood.* The origin of this valuable resin is not precisely known, but it appears to be obtained from several large trees growing in many parts of the East Indies and the Indian Archipelago, of which the most known are the *Calamus Rotang*, and *Pterocarpus Draco*. This resin is very largely mixed and adulterated so that the samples to be found in

the different ſhops, often have ſcarcely any other reſemblance than in colour. The beſt ſort of dragon's blood is found in irregular roundiſh pieces about the ſize of a walnut, often wrapped in palm leaves, and of a deep uniform dull red colour, without ſmell or taſte. When broken, its texture appears homogeneous, but evidently cellular. If a little of it is rubbed much in a mortar the colour brightens, and ſomewhat approaches that of vermillion.

Pure dragon's blood is entirely inſoluble in water, but totally ſoluble in alcohol, forming a tincture of a fine blood-red colour. It burns with a bright flame, and readily conſumes leaving only a ſmall portion of a white aſh. When charred by ſulphuric acid, 100 grs. leave 48 grs. of coal.

Dragon's blood is ſoluble in the eſſential oils, and alſo in the fixed, giving them a fine red colour. This reſin is largely uſed in *Varniſhing*, (which ſee) in lacquering, and painting, where a full bodied deep red is wanted.

10. *Gum Elemi*. This reſin comes over from South America in ſemi-pellucid yellowiſh maſſes generally wrapped up in leaves, and viſibly contaminated with bits of twigs and bark, friable in the fingers, ſoftening by heat, of a fragrant ſmell and bitteriſh taſte. The tree that yields it is ſuppoſed to be the *Amyris Elemifera*.

Water diſſolves only about $\frac{1}{16}$ of this reſin, and the remainder is ſoluble in alcohol.

11. *Gum Hederæ* is a reſin which exſudes in hot countries from the ſtalks and leaves of the ivy, (*Hedera Helix*.)

It appears in hard compact maſſes, reddiſh brown externally, internally of a bright yellow, nearly opake, brittle, and with a gloſſy vitreous fracture. The ſmell is agreeable when rubbed, the taſte ſlightly aſtringent. It is not entirely ſoluble either in water or alcohol, ſo that in ſtrictneſs it ought hardly to be called a true reſin. It is little known, and has not been carefully examined.

12. *Labdanum or Ladanum*. This reſin exſudes ſpontaneouſly from the leaves and branches of a fragrant ſhrub (*Ciſtus Creticus*) which grows abundantly in the dry mountainous regions of the Iſle of Candia, Syria, and other parts of the Levant. Ladanum is a black, hard, heavy, reſinous maſs, rough externally, and in fragments, and its fracture ſhews diſtinct ſparkling particles. When chewed it gives a gritty feel to the mouth, and a bitteriſh taſte, but does not diſſolve. The ſmell is fragrant. When digeſted with water it imparts its grateful ſmell, but does not ſenſibly diſſolve therein. By diſtillation it gives a fragrant eſſential oil, and a taſteleſs brittle reſin remains. Alcohol diſſolves all the reſin, and always ſhews in the undiſſolved reſidue a conſiderable quantity of ſand and other impurities.

13. *Maſtich*. This very valuable reſin is procured from the *Piſtacia Lentiſcus*, a tree that grows to ten or twelve feet high, and is cultivated in many parts of the Levant, particularly in the iſland of Chio.

The beſt maſtich is in the form of ſmall roundiſh tears, hard and brittle, of a faint yellow colour, nearly tranſparent, with a light but pleaſant ſmell, and little or no taſte. When chewed it ſoftens in the mouth, and excites a conſiderable flow of ſaliva. It is nearly inſoluble in water, but gives it a pleaſant flavour when boiled with it. Alcohol and the eſſential oils diſſolve maſtich entirely, forming a clear light-yellow tenacious ſolution, which either alone or with other reſins is much employed in varniſhing and other arts. When charred by ſulphuric acid, 100 grains afford 66 of charcoal.

14. *Sandarac*. This reſin exſudes from the bark of ſeveral kinds of Juniper, and concretes in nearly pellucid yellowiſh tears of a pleaſant ſmell, and ſcarcely any taſte. It is compleatly ſoluble in alcohol, and in oils fixed or eſſential, and is much uſed in varniſhing.

15. *Tacamahacca*. This reſin is obtained from the *Fagara octandra*, a tree found in many parts of South America. There are two ſorts of this reſin; the beſt is collected in gourd ſhells, and is unctuous and ſoft, of a greeniſh yellow colour, a delightful ſmell approaching to that of lavender, and a bitteriſh aromatic taſte. It is ſeldom uſed.

16. *Styrax*, or *Storax*, is a very fragrant reſin procured from the *Styrax officinalis*, a middling ſized tree, a native of Aſia. There are two ſorts of this reſin; the Styrax calamita, compoſed of reddiſh brown maſſes of a waxy conſiſtence, and free from viſible impurities. The other, which is by much the commoneſt ſort, is ſo largely adulterated with ſaw-duſt, that it looks rather like a maſs of ſaw-duſt ſomewhat agglutinated by means of a ſoft clammy reſin. Common ſtyrax infuſed in water gives it a golden colour, a fragrant ſmell, and a ſlight balſamic taſte. Diſtillation with water ſtill further impregnates this liquid with the ſame qualities of ſmell and taſte, and contains *benzoic* acid, which may be extracted in the way mentioned under this article. When ſtyrax is diſtilled *per ſe* it yields

along with an empyreumatic oil some crystallized flowers of benzoin. Alcohol dissolves all the true styrax from the impure mass. In flavour and, when pure, in other properties, this resin strongly resembles the balsam of Tolu.

Gum Resins. These substances, as already mentioned under this article, are not entirely soluble in either water or pure alcohol, singly, but compleatly so in a mixture of the two. Many of them have very strong sensible properties, and they are altogether much more active when used medicinally than the resins. When rubbed with water, they form a thick emulsion, from which most of the resinous part separates by repose.

The gum-resins are principally, though not entirely, used in medicine.

17. *Asafœtida*. This gum-resin is the dried juice of a large umbelliferous plant, (*Ferula asafœtida*,) which grows in the mountains of Persia and Arabia. It is collected by cutting the mature plant a little above the ground, which causes a quantity of white juice to exsude on the cut surface of the stock, that soon concretes into a brownish soft gum. This is removed, a fresh surface is made on the stalks by cutting it down for an inch or two, and more of the juice is collected, till after a time the whole is exhausted, and the stalk dies.

Asafœtida is brought to us in irregular masses mostly of a brownish colour approaching to red, and involving smaller lumps that are nearly white. It has a very strong fetid smell like garlic, extremely permanent and diffusive, its taste is nauseous and bitterish. If rubbed with water it entirely resolves into a milky emulsion, from which after standing for some time most of the resinous part subsides, leaving a clear supernatant liquor containing much gum in solution. Pure alcohol dissolves only the resinons part, and makes a clear yellow solution. Dilute alcohol dissolves the entire resin and forms a brownish, rather turbid tincture Water distilled off asafœtida rises strongly impregnated with its peculiar smell. A hundred grains charred by sulphuric acid yield 58 grs. of charcoal.

18. *Galbanum* is the concrete gummy-resinous juice of an umbelliferous plant of Ethiopia, (*Bubon galbanum*,) and is brought over in pale semi-transparent, soft, tenacious masses, intermixed with clear white tears of the same resin. This juice has a strong unpleasant smell, and a bitterish, warm taste. When rubbed with water it dissolves into a milky emulsion, and has all other chemical properties of the gum resins.

19. *Gum Ammoniacum*, a gum resin brought from the East Indies, composed of small white lumps or tears, more brittle than most of the other gum-resins, and easily reduced to fine powder in cold weather. It unites perfectly with water into a milky emulsion, and water and alcohol separately dissolve only a portion of the gum. It is sometimes employed in a small degree in the composition of cements and varnishes. A hundred grains charred by sulphuric acid give 58 of charcoal.

20. *Opopanax* is a strong-smelling gummy resinous juice procured from the *Pastinaca opopanax*, and brought from Turkey and the East Indies in small round drops or irregular lumps of a reddish yellow colour. It mingles perfectly with water, and agrees in chemical properties with the other gum resins.

21. *Sagapenum*, is a fetid gum much resembling asafœtida, but weaker in sensible properties, it is brought from Alexandria, in soft irregular masses sticking to the fingers when handled. In chemical properties it agrees very closely with asafœtida.

22. *Olibanum*. A gum resin brought from Turkey and the East Indies, in large roundish lumps, semi-pellucid, and when of the purest kind, of a slight yellow colour. When chewed it has a bitterish pungent taste, and makes the saliva milky The smell is moderately strong, and not disagreeable. When laid on a hot iron it burns with a strong, penetrating, and rather fragrant smell, and is supposed to have been used by the ancients for incense.

23. *Gamboge*. For a description of this valuable gum, see the article *Gamboge*.

24. *Euphorbium* is a juice procured from a plant of this name, brought chiefly from Barbary, in drops of an irregular form of a pale yellow, and brittle. This gum-resin has but little smell, but the taste is one of the most biting and acrid of any known substance, and the effect on the organs remains for a considerable time. It consists of about equal parts of gum and resin.

25. *Myrrh*. This gum-resin exsudes from a tree which grows in Abyssinia and many parts of Arabia, but is little known. It comes over in rounded pieces of various size, and still more varying in colour, consistence, taste, and smell. The best sort is semi-transparent, friable, unctuous to the touch, of an uniform light or reddish yellow colour, of a strong but not ungrateful smell, and a slightly pungent and very bitter taste. It burns with some difficulty. It compleatly dissolves in boiling water when previously pulverized, but on cooling, a yellow

resinous sediment falls down. The supernatant liquor evaporated nearly to dryness yields a saponaceous extract, which retains much of the flavour of the myrrh. Alcohol digested with myrrh forms a very strong-smelling, intensely bitter tincture, of a very fine golden yellow colour, which is made turbid by the addition of water.

Guaiacum. This substance has usually been reckoned among the perfect resins, but late experiments (though they are not compleat,) shew that it has some very peculiar properties, so that it cannot be classed properly either with the gums or resins.

This gum is procured from the *Guaiacum wood*, or *Lignum vitæ*, which is a very hard, ponderous wood, obviously abounding with resin, and as it were soaked in it, so that it has a peculiar greasy feel, and a very strong and peculiar smell when rubbed.

Gum guaiacum is brought over in irregular masses, easily friable, of a dusky green colour. It is in some degree transparent, and it breaks with a vitreous fracture. When pulverized, it is of a grey colour, but becomes green on exposure to air.[a] It melts when heated, and gives a very pungent aromatic odour. The smell is fragrant; it gives scarcely any taste in the mouth, but when swallowed, it excites a strong burning sensation in the throat Mr. Hatchett has observed that guaiacum, though apparently a pure resin, differs from all the pure resins in giving much oxalic acid by the nitric, and in yielding scarcely any artificial tannin with the nitric acid. Mr. Brande has since given an interesting analysis of this substance.[b]

When pulverized guaiacum is digested in a moderate heat in distilled water, an opake solution is formed, which becomes clear on passing the filter. This liquor is of a greenish brown colour, and a sweetish taste. The muriats of alumine and tin, and nitrat of silver, all cause a brown precipitate, and when the liquor is evaporated an *extract* is left. One hundred grains of guaiacum yield about 9 grs. of this extract, which also contains some salt of lime, as shewn by the oxalic acid.

Alcohol dissolves guaiacum with ease, leaving about 5 per cent. of extraneous matter undissolved. This solution is of a deep brown colour, and is decomposed by water, which separates the resin and leaves the liquor of a milky hue. If muriatic acid is added to the alcoholic solution, the resin at first separates, which an excess of the acid redissolves. The addition of nitrous ether to the tincture and subsequent dilution with water, causes the resin to precipitate, which soon acquires a fine *blue* colour,[c] and this change of colour appears characteristic of the resin of guaiacum, and has been employed as a means of detecting any adulteration. Liquid oxymuriatic acid added to the tincture also precipitates the resin immediately of the same blue colour.[d] Acetic acid causes no precipitate, the resin being readily soluble in this acid. Nitric acid diluted with one fourth of its weight of water, turns the tincture green, and gives a green precipitate after standing some hours, but the colour soon changes to blue, and afterwards to brown.

Alkalies do not cause any precipitation in the tincture.

The guaiacum in substance shews the following effects with the different reagents.

Sulphuric ether dissolves it though less abundantly than alcohol.

Sulphuric acid acts on it nearly as on the other resins, and finally chars it, leaving 58 grs. of coal from 100 of the resin.[e]

Nitric acid acts upon it in a peculiar manner: 100 grs. of guaiacum were added to 2 oz. of this acid of 1.39 sp. gr.[f] the resin at first became of a dark green colour, a violent effervescence was excited with the production of much nitrous gas, and the whole was dissolved without the assistance of heat. This solution, left at rest for some hours, deposited crystals of oxalic acid. In this last circumstance, and in the ready solubility in cold nitric acid, guaiacum differs essentially from the other resins.

Dilute nitric acid acted somewhat differently, and dissolved only part of the guaiacum, and the remainder was converted into a chocolate brown substance, apparently the same as that produced by adding the same acid to the tincture after it has passed through the changes of green and blue. This brown substance now more compleatly resembles the true resins, being equally soluble in alcohol and ether, and insoluble in water. If this is further decomposed by nitric acid, in the way mentioned by Mr. Hatchett, it is converted into artificial tannin.

The alkalies, pure and carbonated, dissolve guaiacum with ease.

RETORT.

An article of chemical apparatus, for an account of which see the Appendix.

[a] Murray, Appar. Med. Med. vol 3. [b] Phil. Transf. for 1806. [c] Monch, in Crell's Journal, or Murray, Appar. [d] Brande. [e] Hatchett. [f] Brande.

RHODIUM. See PLATINA.

ROCHELLE SALT. See TARTRITE OF POTASH AND SODA.

ROCK CRYSTAL. See QUARTZ.

ROCK SALT. See MURIAT OF SODA.

ROSES, Attar of. See OILS vegetable, eſſential.

ROSIN. See TURPENTINE.

ROTTEN-STONE. See TRIPOLI.

RUBY. See SPINEL.

RUBY oriental. See CORUNDUM.

RUBY OF ANTIMONY. See ANTIMONY.

RUTHIL. See TITANIUM, ores of.

S

SACCHARUM SATURNI, or Sugar of Lead. See LEAD, acetite of.

SACCHOLACTIC ACID. See MILK, p. 100. and MUCILAGE, p. 112.

SAFFLOWER. *Carthamus, or Baſtard Saffron.*

This plant, the flower of which is employed in dyeing and colouring, is cultivated in Spain and in many parts of the Levant,[a] from which it is chiefly imported.

This dyeing material contains two colouring matters, a yellow and red, the former of theſe alone is ſoluble in water and is comparatively of little value, the latter is ſoluble in alkalies and precipitated thence by ſeveral acids and forms a beautiful roſe-red pigment. This is partly uſed for ſilk dyeing, but the great conſumption of it is in the *rouge* ſo celebrated as a coſmetic, and of which it forms the eſſential ingredient.

To prepare the carthamus for this purpoſe it is neceſſary firſt to extract the yellow portion, which is done by tying the plant in a linen bag, and then waſhing it inceſſantly with water, uſing much ſqueezing and rincing till the water paſſes off colourleſs. The reſidue in the linen bag now conſiſts of the fibrous part of the plant and of the valued red fecula, which laſt however is in very ſmall quantity. This is extracted by digeſting the waſhed carthamus in a ſolution of carbonat of ſoda, (without applying artificial heat which would impair the colour,) and this gives an orange yellow alkaline ſolution, which on ſaturation with acids turns red, and gradually depoſits a beautiful red fecula which is the pigment in queſtion. Lemon juice is the acid preferred. But as the colour of this red fecula is extremely intenſe it will bear dilutions, which is done chiefly by rubbing it with finely powdered talc, in different proportions.

Alcohol will alſo diſſolve the red part of carthamus; and after the yellow portion has been extracted by water, a fine red tincture is made by digeſting the reſidue in alcohol.

On account of the high price of carthamus it is ſeldom if ever employed except for giving a finiſhing gloſs to dyed ſilks, and for the preparation of rouge. Alkalies of every kind immediately alter the colour to an orange yellow, again reſtorable by acids.

SAFFRON OF MARS. See IRON, p. 613.

SAHLITE. *Sahlit*, Wern. *Malacolithe*, Hauy.

Its colour is between greyiſh green and pale leek green. It occurs in maſs, and cryſtallized in ſix-ſided priſms. It is moderately ſhining with a waxy luſtre. Its longitudinal fracture is lamellar in three directions. Its fragments are often rhomboidal. It is tranſlucent on the edges; its hardneſs is about equal to that of glaſs. It is very ſmooth to the touch, and is eaſily frangible. Sp. gr. 3.23.

It is fuſible before the blow-pipe with difficulty into a porous glaſs. Its component parts, according to Vauquelin, are

53.	Silex
20.	Lime
19.	Magneſia
3.	Alumine
4.	Oxyds of iron and manganeſe
99.	

This mineral was firſt diſcovered in the ſilver mines of Sahla in Sweden, it has ſince been found at Buoen near Auen in Norway.

SAL AMMONIAC. *Muriat of Ammonia. Salzaures ammoniak.* Germ.

This neutral ſalt, conſiſting of muriatic acid and ammonia, in a ſtate of mutual ſaturation, was not unknown to the ancients. In the time of Pliny it was imported into Europe from Egypt, and continued to be furniſhed by the ſame country to the various States of modern Europe, till within the laſt fifty or ſixty years.

[a] Berthollet Elemens de la Teinture. Beckmann Comment. Gotting. vol. 3 and 4. Dufour An. Chem. Tom. 48.

It has alſo been prepared in India (probably in the ſame manner as in Egypt) from time immemorial. Before treating of the properties of this ſalt we ſhall give an account of its manufacture, firſt in Egypt, and then in the various countries of Europe.

On account of the great want of wood in Egypt the principal fuel of the country is compoſed of the dung of camels, cows, and other domeſtic graminivorous quadrupeds, mixed up with chopped ſtraw and dried in the ſun. The ſoot produced by the combuſtion of this fuel is the material from which ſal ammoniac is prepared, by ſublimation. The veſſels made uſe of on this occaſion, are very thin globular glaſs balloons, with a ſhort neck terminating in a mouth about 1½ inch in diameter. The largeſt balloons are about 36 inches acroſs, but they are of very various ſizes, being capable of containing when three-quarters full, from 12 to 50 lbs. of ſoot. In order to ſecure them as much as poſſible from breaking during the proceſs, they are coated with a mixture of mud depoſited by the Nile, and chopped ſtraw.

It has been affirmed by the Jeſuit le Pere Sicard and ſome others, that the ſoot is mixed with a certain proportion of common ſalt and camels' urine, but this appears to be a miſtake; being abſolutely contradicted by the moſt accurate enquirers. From theſe it appears that no other ingredient is made uſe of but ſoot, with which, moderately preſſed down, the balloons are filled to within about four finger's breadth of the neck. The veſſels thus charged are arranged, to the number of 60 or 70, in an oblong furnace of brick, and ſecured with clay ſo that their necks alone are in contact with the external air. The furnace is now very gradually heated by means of ſtraw for the firſt three or four hours, and afterwards with a mixture of ſtraw and the common fuel of the country, viz. dried dung. In the courſe of ſix or ſeven hours a thick ſomewhat acid empyreumatic ſmoke begins to riſe out of the balloons, and continues for about fifteen hours. The ſublimation of the ſal ammoniac commences three or four hours before the ſmoke ceaſes, and continues from fifteen to forty hours, according to the ſize of the balloon, without any further care being required than to regulate the fire properly, and to paſs an iron rod occaſionally down the necks of the balloons to prevent them from being clogged up by the ſalt as it riſes, and thus producing an exploſion. When the ſublimation ceaſes, the fire is allowed to go out, and the veſſels as ſoon as they are ſufficiently cool are removed from the furnace and broken; the cake of ſal ammoniac, which occupies their upper part, is in the form of a very ſhallow baſon, and weighs on an average ſomewhat more than ⅙ of the ſoot employed; it has generally a yellowiſh white tinge and is apt to be fouled with a little charcoal, eſpecially if the heat has been too great.

The proportion of ſalt from a given quantity of ſoot is liable however to conſiderable variation: it is found that the dung of the ſame animal affords a ſoot much richer in ſalt when it is fed on freſh vegetables than on hay and other dry food. There is beſides a great difference in the ſoot from the dung of different animals ſimilarly circumſtanced as to food. According to Mr. Granger, the Egyptian ſal ammoniac makers eſteem the ſoot of cow-dung when the animal is fed on graſs, to be by far the beſt, 26 lbs. of this affording no leſs than 6 lbs. of ſalt. According to Haſſelquiſt, however, the ſoot from the dung of goats and ſheep is in the higheſt eſtimation.

In this very ſimple manufacture, the ſal ammoniac appears to exiſt ready formed in the ſoot, and the action of the heat is confined to the mere ſeparation of the ſaline from the other ingredients. The ſoot itſelf is of a deep black colour, has very ſenſibly the taſte of ſal ammoniac, and when ſtrongly heated gives out a ſulphureous odour.

In Europe, where dung is employed to better purpoſe than for fuel, the manufacture of ſal ammoniac is a much more complicated proceſs, eſpecially when carried on in the beſt and moſt economical manner. A kind of intermediate method however is practiſed with ſucceſs in ſome eſtabliſhments in the Netherlands, of which the following are the principal details.[c]

A kind of fuel capable of furniſhing ſal ammoniac by its combuſtion, is firſt prepared, the ingredients of which are

25 parts by meaſure of pulverized pit coal
5 do. ——— of common chimney ſoot
2 do. ——— of clay

To theſe is added a ſaturated ſolution of common ſalt in ſufficient quantity to bring the whole to a conſiſtence for being moulded into balls. The balls are of an oval form, and after being dried in the air are ready for uſe.

[b] Lemére in Mem. de l'Acad. des Sciences, 1720, p. 191. Granger in ditto, 1735, p. 107. Haſſelquiſt in Phil. Tranſ. vol. LI. p. 504.
[c] Journ. des Mines, No. 16, p. 3.

The apparatus for collecting the soot produced by the combustion of this fuel, consists of a brick furnace communicating by a flue 2 inches in diameter, with a vaulted chamber, also of brick, from the opposite extremity of which there passes out a flue of the same diameter as that already mentioned, terminating in a horizontal gallery, at the end of which is the chimney. The furnace is charged with the balls above mentioned, to which is added a somewhat variable proportion of dry bones; and with these materials an incessant fire is kept up for from four to six months. At the expiration of this time, the vaulted chamber and gallery are opened and the soot with which they are lined is scraped off from the top the sides and floor, observing to keep the soot from the latter distinct from the rest.

The principal new combinations that take place in consequence of the combustion appear to be the following: first, the *pit-coal* is resolved into gas of various kinds, into empyreumatic oil loaded with finely divided charcoal, and into carbonated ammonia: the *soot* forms carbonic acid, and also gives out the carbonated ammonia which it contained: the *bones* afford empyreumatic animal oil and carbonated ammonia; and the *common salt* by the action of the clay is decomposed, its alkaline base remaining united to the earth, and its acid passing in a gaseous state into the chamber, where it meets with and decomposes the carbonated ammonia, forming sal ammoniac. Hence the contents of the soot collected in the chamber are carbonaceous matter, muriat of ammonia, and empyreumatic bituminous oil; the latter of which is particularly abundant in the soot that concretes on the floor.

To separate the sal ammoniac from the other ingredients sublimation is had recourse to, and is thus performed. Several egg-shaped jars, made of earthenware, about 2[illegible] inches high and 16 in diameter, with a mouth 2½ inches wide, are fixed in a furnace, and as soon as they are become moderately warm are charged with soot, broken into small pieces, to within three inches of their mouths; a duly regulated heat is then kept up for 48 hours, in which time the volatile oil first rises and passes out into the air, then the sal ammoniac sublimes and fixes itself to the upper part of the jars, while the earthy and carbonaceous impurities remain at the bottom: the vessels are then broken and the cakes of salt extracted. Fifteen pounds of soot afford on an average about 5lbs of muriated ammonia. The soot from the floor of the chamber is too much loaded with bitumen to admit of the salt being extracted from it by simple sublimation, and the most economical way of treating it is to burn it over again, by which the bitumen is destroyed, and the sal ammoniac mixed with the soot, rises uninjured into the chamber.

The method of carrying on the manufacture of this salt in England, though more complicated than the above, is, we apprehend, considerably more economical. The following[d] was the actual practice at a large establishment near London, which was abandoned a few years ago in consequence of Glauber's salt being subjected to the excise.

The material from which the ammonia was extracted was bones. These were collected in the streets and from dunghills, chiefly by old women. The bones having been thus procured, were chopped into small pieces either by hatchets or machinery, and then boiled, in order to extract the grease or fat and marrow remaining in them, which was sold to the soap-boilers. The bones were then thrown into a cylindrical iron still, about 3 feet in diameter, and 8 or 9 feet long, laid horizontally over a fire-place, so as to be capable of being made moderately red-hot. At one end of the cylinder was a mouth about 14 inches in diameter, by which the bones were introduced, and furnished with a cover capable of closing it accurately by the help of a little lute. From the other end of the cylinder proceeded a cast iron pipe, from 6 to 8 inches in diameter, and 18 or 20 feet long, terminating in one or more oblong leaden receivers, which were kept cool by water, placed in a vessel of the same materials, the bottom of which formed their cover, the juncture being secured by lute. Of these receivers there were commonly two to each still, or three to two stills. Every receiver was about 12 feet long, 1 foot deep, and 14 inches wide, and the refrigeratory which covered it held about 4 inches in depth of water: at the end the most remote from the still was a pipe, fitted with a wooden plug for the purpose of drawing off the condensed liquor, and above this was a hole through which the gas and incondensible vapour passed off into the open air.

A single charge of each still yielded about 36lbs. of impure alkaline liquor, and about 30lbs. of black fetid oil floating upon its surface. This latter being skimmed off, the alkali was

[d] Original Communication.

saturated with sulphuric acid, either by the addition of the mother liquor from the green vitriol makers (consisting for the most part of red sulphat of iron); or still more economically by means of calcined and pulverized gypsum: in this latter case after mixing the materials and stirring them well together, they are to be left at rest for some hours, during which a double decomposition takes place, the sulphat of lime yielding part of its acid to the ammonia, and at the same time depriving this latter of its carbonic acid. The solution of sulphat of ammonia thus produced is then mixed with common salt, by which another decomposition takes place, the alkali of the former and the acid of the latter uniting to form muriat of ammonia, while the two remaining ingredients produce by their combination sulphat of soda.

The liquor containing these two salts is then clarified by subsidence and decantation, and transferred into oblong leaden boilers, about 9 feet long, 3 wide, and 9 inches deep. The boilers are set for about $\frac{2}{3}$ of their length on iron plates, heated by a fire beneath, the remaining part being supported by flat tiles defended by solid brick-work from the access of the heat. As the water evaporates the Glauber salt begins to crystallize, and is swept from time to time to the cool extremity of the boiler, whence it is shovelled out into baskets arranged over the end of the boiler, that the liquor which drains from the small granular crystals may not be lost. The evaporation is continued for several hours, till as much as possible of the Glauber's salt has been separated, and the muriat of ammonia begins to crystallize on the surface of the liquor in the form of feathered stars. The remaining fluid is then run off into coolers, and deposits little else than muriat of ammonia, till it gets below the temperature of 70° Fahr. at which time the crystals are to be removed, lest they should be mixed with Glauber's salt, which now begins to be again deposited. After the muriat of ammonia has been suffered to drain in the baskets, it is removed to a kind of oven, or even an open tiled hearth heated from below, where the water of crystallization is driven off, by which the salt becomes spungy, friable, and of an ash or slate colour, interspersed with small white filaments.

The salt is now removed while hot into globular glass receivers, or more commonly glazed earthen jars, fitted with a cover (having a hole of above half an inch diameter in its centre) luted on with a mixture of clay and horse-dung. These are set in iron pots over a strong fire, in a furnace of either a circular or oval form, and capable of containing from six to eighteen, surrounded with sand up to the edge of the pot, and also having about two and a half inches of sand on the cover, confined by an iron ring about three inches deep, and two inches less in diameter than the cover, in order that if the luting should give way in any part, it may be repaired without suffering the covers (which should be kept during the sublimation at about 320°) to be cooled by the removal of a large portion of the sand. These earthen pans may be filled to within two inches of the top, with the dried salt gently pressed in, but not rammed close; and the fire, which has been lighted some time before, is now to be raised gradually till the iron pots are of a pretty strong red heat all round, being so placed in the furnace that the upper part may be first heated, the bottom resting on solid brick-work. During the first impression of the heat a portion of the salt carrying with it a quantity of watery vapour not separated on the drying place, will escape through the hole in the cover, which must be left open till all the aqueous particles are exhaled: this is known by bringing a piece of cold smooth iron plate near the hole in order to condense the sublimate, which, becoming more and more dry, at length attaches itself firmly to the plate, in the form of a dry semi-transparent crust. At this time the hole is to be stopped with a bit of lute, more sand is to be put on the cover, and the heat continued till it is judged that nearly the whole of the muriat of ammonia is sublimed. The time requisite for this purpose depends on the structure of the furnace, the size of the pots, the briskness of the fire, and other circumstances only to be learnt by experience. The process should be stopped before the sublimation has entirely ceased, as the heat in some parts of the jar may be too great when it is nearly empty, and either by burning a part of the salt itself, or elevating a portion of foreign matter from which it can never be kept wholly free, give the cake a yellow tinge, and a scorched, opake, crackled appearance. The same defects are likely to happen, when any part of the luting having given way, is obliged to be repaired by wet lute, when the sublimation is pretty far advanced: consequently glass vessels are preferable, except on account of the expence, as they must always be broken to pieces in order to get out the cake: the jars on the contrary will serve for several sublimations, even the covers, if well glazed, will last two operations. The sublimation being finished and the apparatus having become

sufficiently cool, the tops of the jars are to be taken off, and the cakes of sal-ammoniac that are found adhering to them are to be separated, and placed for a day or two in a damp atmosphere, which softens their surface a little, and thus facilitates the removal of any superficial impurities. Lastly, the cakes are packed up in casks for sale.

The following is a table of the proportions of dry carbonat of ammonia afforded by different substances:

Horn - - -	$\frac{1}{5}$
Feathers - -	$\frac{2}{11}$
Wool - - -	$\frac{1}{6}$
Soot - - -	$\frac{1}{15}$
Bones - -	$\frac{1}{16}$
Blood - - -	$\frac{1}{17}$
Putrid urine -	$\frac{1}{46}$

In common manufactories the dry carbonat yields rather less than $\frac{2}{3}$ of sal-ammoniac. In most of the Scotch manufactories soot is used instead of bones, these latter being only to be procured abundantly in the vicinity of a very large town.

Muriat of ammonia prepared by any of the above methods, possesses the following properties. It has no smell. To the taste it is bitter, pungent, and urinous, and at the same time cooling: its colour, when perfectly pure, is a bluish-white: its texture when sublimed is fibrous: it is tough, moderately elastic, and somewhat ductile, and hence is not very easily reducible to powder. Its primitive crystalline form is the regular octohedron, but when crystallized from its solution in water it is either in long tetrahedral pyramids or in flaky feathered crystals: when sublimed it sometimes forms rhomboids, approaching very nearly to the cube: the former crystals are somewhat deliquescent, but the latter, as well as every other sublimed variety of this salt, are permanent in the air. Sp. gr. 1.42.

It is soluble in about thrice its weight of water at the ordinary temperature, and produces much cold during the solution: boiling water takes up its own weight of this salt, part of which as the solution cools is deposited in beautiful feathery crystals.

When exposed to a dry heat somewhat exceeding that at which lead melts, it begins to rise in the form of a white vapour (without previously entering into fusion) which has a peculiar odour, and attaches itself to cool surfaces. It is generally represented as undergoing no change by this process, but according to Beaumé, after repeated sublimations it begins to be decomposed, a little ammonia being first discharged, and afterwards some muriatic acid gas.

Muriat of ammonia is decomposable with abstraction of its acid by the caustic fixed alkalies and by all the alkaline earths, more especially if a moderate heat is applied: the ammonia is volatilized in the form of gas, and the acid remains behind in combination with the added alkali. If a carbonated instead of a pure alkali is employed, and sublimation is had recourse to, the ammonia rises in a mild or carbonated state.

Many of the metals and metallic oxyds are also capable of decomposing muriat of ammonia in the dry way, ammoniacal gas being disengaged, and the metal remaining behind in the state of muriat. It is a remarkable circumstance that many metals when thus treated are converted into muriated oxyds, although liquid muriatic acid has no effect upon them, thus mercury when triturated accurately with sal-ammoniac and heated, disengages ammoniacal gas, and muriated mercury is the result, if however an excess of ammoniacal muriat is present, this excess combines with the muriat of mercury, forming the sal-alembroth, as we have mentioned under the article MERCURY. Silver by a similar treatment decomposes sal ammoniac, and is itself converted into luna cornea.

Sulphuric acid is capable of decomposing muriat of ammonia by distillation, the muriatic acid being volatilized and sulphat of ammonia remaining in the retort. Nitric acid and muriat of ammonia re-act upon each other; the muriatic acid being liberated from its base by part of the nitric acid, while another portion of the same is decomposed, and its oxygen passes to the muriatic acid, thus converting it into the oxymuriatic: hence the old chemists were in the habit of composing an aqua regia, by dissolving sal ammoniac in nitrous acid, for dissolving gold; the occasional bad consequences of which we have mentioned when treating of that metal.

The action of nitre and sal ammoniac in solution has not been investigated; but if the latter salt is added to nitre in fusion a partial deflagration takes place, no doubt in consequence of the mutual decomposition of the ammonia and nitric acid.

According to Gellert a boiling hot solution of muriated ammonia is capable of dissolving vegetable resin.

The action of sulphur and sal ammoniac on

each other has been fcarcely examined into. Pott affirms, that if one part of the former and two of the latter are fublimed together, the inflammability of the fulphur is deftroyed.

The water of compofition contained in fal ammoniac is the fame in quantity according to Beaumé, whether the falt is fublimed, or cryftallized from its aqueous folution. With this Mr. Kirwan agrees, who ftates the component parts of fal ammoniac, whether fublimed or cryftallized, at

42.75	Muriatic acid
25.	Ammonia
32.25	Water
100.00	

The ufes of fal ammoniac are confiderable. Befide being employed in the laboratory as the fubftance from which pure and carbonated ammonia are procured, it is ufed in fubftance by the dyer, the refiner of gold, the copper-fmith, and the manufacturer of tin-plate.

SAL AMMONIAC, NATIVE. Naturlicher Salmiak. *Wern.*

Its colour is greenifh-white, paffing to apple-green, or brownifh-black. It occurs in thin fuperficial efflorefcences, or maffive, or ftalactical, or rarely in minute imperfect cryftals. It has in general a flight vitreous luftre. Its fracture is fine-grained uneven. It is foft, often friable. It has a pungent bitter faline tafte. In chemical characters it agrees with the manufactured falt.

It is found fublimed in the crevices of volcanoes; fuch as Etna, Vefuvius, the Solfatara, and the Lipari iflands.

SAL DIURETICUS. See ACETITE OF POTASH.

SAL GEM. See MURIAT OF SODA *Native.*

SAL MARTIS, is the green *Sulphat* of IRON.

SAL POLYCHREST, is SULPHAT of *Potafh* calcined with a very fmall portion of fulphur, formerly ufed in medicine.

SAL PRUNELLA, is NITRAT of *Potafh*, from which the water of cryftallization has been expelled by fufion.

SALIVA. This fluid, analyzed by Vauquelin, was found to confift of water holding in folution a fmall quantity of mucus and muriat of foda.

SALT. This term has been fo varioufly applied that it is fcarcely poffible to give an accurate definition of it. The general and the moft antient idea of a falt is, a cryftallizable fubftance, confiderably foluble in water, and highly fapid, but the term is at prefent applied to all the cryftallizable acids or alkalies, or earths, or combinations of acids with alkalies, earths, or metallic oxyds. Hence the common and ufeful diftinction of the compounded falts into *alkaline*, *earthy*, and *metallic*. In fo doing however, and by including all the cryftallizable combinations of acids and bafes, fome compounds have got the name of falts which want the primary, and what would formerly have been confidered as effential, qualities of folubility and fapidity, of which fulphat of barytes is an example, which is abfolutely infoluble in water and taftelefs. It is ftill however cryftallizable or found cryftallized, which appears to be an invariable character of a falt. Thus this appellation was long denied to carbonat of magnefia, till the difcovery of the cryftallizable foluble carbonat of this earth.

There are many triple combinations alfo of thefe ingredients which belong to the clafs of falts, fuch as alum, tartarized antimony, &c.

Salts are alfo either *neutral* (that is where the ingredients are in exact faturation) or with the acid in excefs, of which tartar is an example, or with an excefs of the bafe, as in borax. Thefe circumftances have been ingenioufly diftinguifhed in nomenclature by Dr. Thomfon, by the prefix *fuper* in the firft cafe, and *fub* in the latter. Thus tartar is named with propriety the *fuper-tartrite of potafh*; borax, the *fub-borat of foda*, &c.

The chemiftry of falts, taken in the moft extended fenfe, forms by far the largeft part of the whole fcience.

The term *Salt* is alfo ufed emphatically for common falt, or muriat of foda.

SALT *Bitter, Purging,* or *Epfom.* See SULPHAT *of Magnefia.*

SALT *Glauber's.* See SULPHAT *of Soda.*

SALT *of Hartshorn.* See CARBONAT of *Ammonia.*

SALT *Sedative.* See BORACIC *Acid.*

SALT of *Seignette* or *Rochelle.* See TARTRITE of *Soda* and *Potafh.*

SALT of *Silvius.* See ACETITE of *Potafh.*

SALT of *Sorrel.* See OXALAT of *Potafh.*

SALT, *Spirit of.* See MURIATIC *Acid.*

SALT of *Tartar* }
SALT of *Wormwood* } See CARBONAT of *Potafh.*

SALTPETRE. See NITRAT of *Potafh.*

SANDARACH. See ARSENIC, *Sulphuret of.*

SAND-BATH. See the Appendix on Chemical Apparatus.

SANDIVER, is the ſcum and ſediment of the large crucibles uſed in the making of GLASS, which ſee.

SAND. *Sand*, Germ. *Sable*, Fr.

SANDSTONE. *Sandſtein*, Germ. *Gres*. Fr. The eſſential component part of ſandſtone is quartz in rounded grains of various ſizes, from the ſmalleſt that are viſible to the naked eye to thoſe that are about the magnitude of a muſtard ſeed. All ſandſtones are ſtratified, but in ſome beds there alſo occur pretty regular fiſſures in two directions perpendicular to the ſtratification, thus dividing the ſtone into parallelopipedal maſſes. When diſintegrated it forms SAND.

There are ſeveral diſtinct formations of ſandſtone, but mineralogiſts are by no means as yet agreed with reſpect to their number; the four following, however, are made out with tolerable accuracy.

1. Primitive calcareous ſandſtone.

Its colour is for the moſt part greyiſh or greeniſh grey. It occurs in maſs. Its fracture is ſplintery; its fragments are blunt-edged; it is tranſlucent at the edges, is moderately hard, giving a few ſparks when ſtruck againſt the ſteel. It efferveſces with acids, and when its calcareous cement is diſſolved out, there remains a very friable maſs of fine white ſand. It does not appear to contain any extraneous minerals. It reſts upon gneiſs and large-grained granite.

2. Ferruginous ſandſtone.

The colour of this is for the moſt part ochery red or reddiſh brown, ſometimes though rarely it is yellowiſh white. Its fracture is very coarſe ſplintery; it is opake and ſoft, being reduced to ſand by a moderate blow. It ſeldom efferveſces with acids, its cement being almoſt always iron ochre with a little clay. It readily diſintegrates by expoſure to the weather. It contains not unfrequently extraneous minerals, ſuch as reddle in ſmall fragments, vitreous copper and other ores of this metal, and very rarely galena, alſo petrified wood. In Thuringia it is covered with bituminous marlite.

3. Gritſtone.

Of this there are two varieties, the compact and ſchiſtoſe.

The former is of a greyiſh white colour, ſometimes ſpotted or ſtriped with ochre yellow. Its fracture is coarſe ſplintery. It very rarely efferveſces with acids. It is harder than the preceding and gives lively ſparks when ſtruck againſt the ſteel. It is not readily decompoſed by expoſure to the air.

The ſchiſtoſe grit differs from the preceding in its fracture which is coarſe ſlaty, and in being more eaſily pulverizable. It is ſometimes intimately mixed with clay and then forms the common *flag-ſtone*, in which ſtate its croſs fracture is earthy, and it contains impreſſions of ſhells.

Gritſtone generally occurs in the independent coal-formation, and contains few extraneous minerals except mica which is particularly abundant in the ſchiſtoſe variety. The elaſtic quartz or flexible ſandſtone of South America, appears only to be a kind of ſchiſtoſe grit.

4. Soft calcareous ſandſtone. Molaſſe, *Fr*.

The uſual colour of this is light greyiſh or yellowiſh. Its fracture is coarſe ſplintery, paſſing into granular. It is ſoft, and when in the quarry is almoſt friable, but hardens by expoſure to the air. Its cement is calcareous.

It occurs alternating with oolite and the other moſt recent varieties of limeſtone.

The uſes of ſandſtone are very conſiderable. It is the ſtone moſt commonly employed in architecture; the ſchiſtoſe varieties are uſed as flag-ſtones, and for covering houſes, for which laſt purpoſe however they are inferior to ſlate; the harder kinds of gritſtone are made into grindſtones, and on account of their infuſibility are employed for lining furnaces, &c.

SAP. The ſap of trees is a watery mucilaginous liquid, often ſtrongly ſaccharine, ſo as even to yield a large quantity of ſugar, and to furniſh a very ſtrong fermented liquor, and containing ſeveral other ſaline ſubſtances. It appears to vary conſiderably in its compoſition, and to fall very far ſhort of the uniformity which diſtinguiſhes the common juice of animals.

The mode of extracting *Sugar* from the ſap of the maple, will be mentioned under that article.

Vauquelin has made an uſeful though incompleat analyſis of the ſap of ſeveral of the common trees, chiefly with a view to the ſaline and earthy contents, and has diſcovered the preſence of acetite of potaſh in all of them, which entitles the acetous acid to be ranked among the native acids as well as being a product of fermentation.

The following is a ſhort abſtract of Vauquelin's experiments.[a]

Sap of the Elm. This juice, which was col-

[a] An. Chim. tom. xxxi.

lected in the spring, has a yellowish red colour and mild and mucilaginous taste, and shews no excess of acid.

Ammonia produces an abundant yellowish precipitate, resoluble in acids with effervescence, and which consists chiefly of carbonated lime with a little vegetable matter. Barytic and lime-water produce the same. Oxalic acid and nitrat of silver give a white precipitate, sulphuric acid excites a strong effervescence, and the gas has a powerful smell of acetous acid. Oxymuriatic acid gives a yellow precipitate, and alcohol a flocculent one. This liquor was analysed in the following way; 1039 grammes were heated in an open vessel and during the evaporation a brown earthy matter gradually fell down and fixed to the sides of the vessel. When nine-tenths of the liquid were wasted by slow evaporation the residue was cooled, and the brown earth was separately treated with muriatic acid which dissolved a portion with effervescence, and left an insoluble portion, which when washed and dried amounted to 637 grammes. The muriatic solution, decomposed by carbonated potash gave 0.5 grammes of carbonat of lime. The evaporated liquid freed from the earthy deposit, still contained much flocculent matter which was separated by filtration and weighed when dry 43 grammes, part of which dissolved in muriatic acid, and produced by precipitation .318 grammes of carbonat of lime, and .425 of insoluble vegetable matter remained. The concentrated and filtered liquor was finally evaporated to dryness and gave 9.553 grammes of a grey extract, strongly deliquescent, and with a pungent saline taste. Sulphuric acid added to it gave a strong smell of radical vinegar, and a notable quantity of this latter acid was procured by distilling the extract with sulphuric acid.

The author estimates the above 1039 grammes of sap to contain .795 grammes of carbonat of lime; 1.06 of vegetable matter; and 9.24 of acetite of potash. The latter however is probably given by estimation from the quantity of acetous acid obtained by distillation, and is therefore liable to much uncertainty, and if the particulars of the analysis are correctly given, the carbonat of lime ought to be .818 (.318+.5) instead of .795. The accuracy of these numbers however is of less importance, as there is no doubt that the varieties of soil, season, climate, &c. influence much the composition of the sap.

Sap of the Ash. This juice had a reddish brown colour, and an astringent taste like the infusion of tan. With reagents it was similar to the last, except that sulphat of iron was blackened with this sap, and animal jelly gave a precipitate. It contained a little acid in excess, a calcareous salt, gallic acid and tan, besides a vegetable extract, and a slight trace of ammonia. The extract left after evaporation to dryness and calcination was found to contain a little alumine.

Sap of Hornbeam. This juice is colourless and limpid in its natural state, has a soft and decidedly saccharine taste, a smell resembling whey, and a considerable excess of acid. When exposed to the air undisturbed for a length of time, it first becomes milky, and throws up a slight down on its surface, then it parts with much carbonic acid, afterwards it acquires a vinous smell and taste, and at the same time its acidity increases, and it becomes limpid from the subsidence of some kind of mucilage. In about five or six weeks, in the summer time, this spontaneous acidity is at its highest, after which it sensibly diminishes, a thick white mucilaginous mould forms on the surface, all taste of an acid is gone, and the liquor only tastes mouldy. The same substance, kept in a closed bottle, remains apparently but little altered, except that there is so great a generation of acetous acid that the liquor would make by itself a good substitute for vinegar in the seasoning of food.

Sap of Birch. This is a colourless saccharine acid liquor which is fermentable in its natural state, and its extract left after evaporation is equally so. The author attempted but without success, to extract sugar from it by the usual means.

Though this excellent chemist has not mentioned it in this place, it is probable that these saps also contain a quantity of *malat of lime*, the extraction of which is described under that article.

SAPPARE. See CYANITE.

SAPPHIRE. See CORUNDUM.

SARDONYX. See CHALCEDONY.

SASSOLIN. Is the native BORACIC ACID of Sasso in Tuscany, which see.

SATTIN SPAR. See LIMESTONE fibrous.

SATURATION.

A substance is said to be saturated with another, either (in the case of simple solution) when the solvent will take up no more of the substance dissolved, or (in the case of mutual chemical action) where the compound produced is perfectly neutralized.

SAUNDERS WOOD.

There are three ſpecies of wood known by this name, the *White*, the *Yellow*, and the *Red*. Of theſe the two former were never employed but in medicine, and are now entirely diſuſed. Theſe two are procured from varieties of the ſame tree, but the tree that yields the red ſaunders is a totally different ſpecies.

White and Yellow Saunders Wood. Theſe woods are brought over in large billets from ſeveral parts of the Eaſt Indies, and are ſaid to be chiefly the produce of the iſland Timor in the Indian Ocean. The white Saunders is of a pale yellowiſh white hue, and almoſt taſteleſs. It is ſeldom ſeen and requires no further notice in this place.

The yellow Saunders is of a pale yellowiſh colour, a fragrant roſe ſmell, and a bitteriſh aromatic taſte. There is ſome doubt whether it is not the ſame tree that yields both the white and yellow, according to the difference of age and ſoil. Both woods are hard and heavy.

The yellow Saunders diſtilled with water gives a fragrant eſſential oil which thickens in the cold to the conſiſtence of a balſam. The watery decoction yields a bitteriſh ſomewhat pungent extract.

Alcohol forms a fine yellow tincture, which after the ſpirit has been evaporated leaves a ſemi-fluid fragrant reſin.

This wood is ſcarcely ever uſed in Europe, but is much valued in the Eaſt for its fragrant ſcent.

Red Saunders Wood. This wood (yielded by the pterocarpus ſantalinus) is alſo brought from the Eaſt Indies, and comes over in round billets of a blackiſh red on the outſide, but of a deep brighter red within and a wavy grain. Though when recent it appears to be highly fragrant, it is nearly without ſmell or taſte in the ſtate in which we receive it, and is ſolely valuable for the deep red it gives out to alcohol. Water digeſted with it has no effect on the red tinge, and only becomes of a pale yellow, but alcohol readily acquires a fine bright full-bodied red. This tincture yields a dark red extract amounting to near a fourth of the weight of the wood. The fixed oils are not coloured by red Saunders; but a few of the volatile oils receive a red tinge. This wood is often confounded with Brazil wood, as they much reſemble each other in appearance. They are however readily diſtinguiſhed by this circumſtance, that Brazil wood gives out its red colour to water as well as alcohol, but Saunders wood only to alcohol.

This latter circumſtance renders this wood of no uſe in general dyeing, but it is occaſionally uſed for colouring ſpirits, as, for example, the red ſpirit uſed for thermometers.

SEA-WATER.

The compoſition of ſea-water and the mode of extracting the ſalt from it are deſcribed under the article MURIAT *of Soda*. See alſo SULPHAT *of Magneſia*; and WATERS, *Mineral*.

SEBACIC ACID, or *Acid of Fat*. *Fettſaure*. Germ.

When any kind of animal oil is ſubjected to a heat ſufficient to volatilize it, ſeveral new products are formed, and among others a very pungent acid liquor may be collected by condenſation, which has been particularly examined by ſeveral chemiſts, and having been conſidered as a peculiar acid it has been termed the *Acid of Fat* or *Sebacic Acid*. A ſimilar acid may alſo be procured from fat without diſtillation of the entire fat, in the way that will be preſently mentioned, whence this acid has been ſuppoſed to exiſt naturally in fat in intimate union with the oily part. The properties of this acid, and the products of the diſtillation of animal oil have been particularly noticed by Crell in two very elaborate memoirs, publiſhed in the Philoſophical Tranſactions,[a] of which we ſhall give a very ſhort extract.

Since this period however another acid ſubſtance differing from the former in many eſſential particulars (eſpecially in being free from ſmell) has been diſcovered by Thenard,[b] which he conſiders as the true ſebacic acid, and the pungent acid of Crell and other chemiſts, he aſſerts to be chiefly a modification of the acetous acid. But as ſeveral objections might be raiſed againſt this opinion, we ſhall give the experiments of each chemiſt.

Thoſe of Crell are in a few words, the following:

A quantity of beef ſuet was firſt melted and ſtrained to ſeparate all the impurities: 2 lbs. of this were put into a glaſs retort ſet in a reverberatory ſand-bath, and a receiver was cloſely luted on. Heat was applied, by which the ſuet firſt melted then diſtilled quietly with a gentle frothing. There firſt came over into the receiver a thin limpid oil which did not congeal, after which came an acid liquor, mixed with a denſer and coloured oil, the former of which remained fluid, but the latter congealed in the receiver. This mixed product continued for ſixteen hours, at the end of which the retort was fully red-hot, and every thing

[a] Vol. 70 and 72.

[b] An. Chim. tom. 29.

volatile had distilled over. On opening the receiver when cold, a most pungent suffocating fetid vapour exhaled, which is characteristic of this process, and the receiver contained three substances, namely, a congealed oil of the consistence of hog's lard, and strongly pungent, over which swam two liquors perfectly distinct, the upper of which was a greenish limpid oil, and the lower was a most pungent gold coloured acid liquor. The retort contained about 1½ oz. of a smooth glossy charcoal. The congealed oil still retained much of the acid liquor, which was separated by melting and washing with hot water. This washed oil was subjected to separate distillation, by which it was again resolved into a congealable oil, and an acid liquor, and the same process was repeated successively with each product of congealed oil after washing, till all the acid liquor which it would yield was got out. By a succession of distillations of the congealed residue, the quantity of it gradually diminished, and at last it finally disappeared; so that the whole 2 lbs. of suet was resolved into various liquid products, and a carbonaceous residue. The former were all mixed together, and then spontaneously separated into two liquors, one a golden coloured acid, weighing 3 oz. 5 drams, the other a yellowish brown oil, weighing 21½ oz. The charcoal weighed 5 oz. 2 scruples, which weights added together left a deficiency from the original quantity of suet, amounting to 1 oz. 6 drs. 1 scr.

We shall not follow this laborious chemist in his experiments on the oil and the charcoal, except to mention that the former after washing to separate the adhering acid, yielded by distillation in a very gentle heat with water, a limpid oil resembling that of *Dippel*, already mentioned under the article *Bone*.

The acid liquor which was brown, was then distilled *per se* in a gentle heat, by which a yellowish white and rectified acid liquor was obtained, and a carbonaceous greasy mass remained in the retort. This rectified liquor was then combined with the several alkaline, earthy, and metallic bases, with many of which it united very readily, effervescing strongly with their carbonats and producing neutral salts, some of which will be presently described.

The same ingenious chemist succeeded in concentrating this acid by saturating the acid liquor with potash, evaporating and thoroughly drying the salt, and then decomposing it by the sulphuric acid and distillation, by which a strong limpid acid was obtained.

But as this method was attended with much trouble and waste, the following mode was employed as an improvement in the process: a ley of caustic potash was made with a pound of salt of tartar, and half a pound of quicklime, which was dissolved in 6 lbs. of water. A fourth part of this was boiled with a pound of suet, and the whole evaporated till it began to stiffen considerably. The remaining three fourths of the ley were then added, and the whole was boiled with a slow fire and constant stirring, till the mixture became pellucid, and when cold concreted into a kind of gelatinous soap. This was then dissolved in water and some powdered alum was added, which immediately produced a decomposition, the oil of the soap uniting solely with the alumine into an insoluble curdy mass. The addition of alum was continued till the formation of this curdy mass had ceased, and the liquor separated from it now contained sulphat of potash, and another neutral salt of potash, and the acid of fat. This was evaporated to dryness and then put into a retort, to which was added a third of its weight of oil of vitriol, which immediately extricated grey vapours strongly impregnated with the peculiar smell of the acid of fat. By applying a very moderate heat, all the acid of fat was expelled, unmixed with sulphuric acid, and it condensed into a fuming, limpid, strong acid of fat, which when added to a solution of acetited lead produced a precipitate which was again soluble in an excess of acetous acid, and therefore contained no sulphuric acid.

When this limpid acid of fat was distilled in a retort till half the quantity had come over clear and colourless, the residue now acquired a golden colour, and deposited brown streaks. The limpid acid in the receiver, again distilled *per se*, again resolved itself into another limpid fluid which passed over into the receiver, and the residue as before deposited these brown streaks. This was repeated eight times, always selecting the clear liquid which had been distilled over in the previous operation, and, to the last, a quantity of brown insoluble matter was left behind, whilst the distilled acid gradually lost its pungency, and somewhat of its acidity, by these successive processes.

There are at least three ways of obtaining this volatile acid of fat; one is by mere distillation of any animal fat, separation of the acid liquor from the other products, and rectification in the way already mentioned, and in this way no intermede whatever is employed. Another way is by decomposing an animal alkaline soap by alum, and distilling the clear remaining residue

with ſulphuric acid; and a third, which indeed ſomewhat reſembles the laſt, and was employed by De Segner, previous to Crell's experiments, is to ſaturate the diſtilled acid liquor with potaſh, and then to decompoſe it by diſtillation with half as much ſulphuric acid as there was carbonat of potaſh employed.

The ſame acid may alſo be prepared according to Guyton, in the following way: mix any kind of animal fat with ſome powdered quicklime, melt the mixture in an iron pot for a time, and when cold, lixiviate the reſidue with warm water, which diſſolves out the ſebat of lime. Evaporate this liquor to dryneſs, by which a brown ſalt is left, which calcine in a crucible, then lixiviate and filter the ſolution, and evaporate to dryneſs. Laſtly, decompoſe this calcareous ſalt by ſulphuric acid, and the limpid pungent acid of fat will riſe.

Before we proceed to deſcribe the *Sebats*, we ſhall mention that peculiar acid diſcovered by Thenard, which alone he conſiders as pure ſebacic acid. His proceſs was the following: A large quantity of pork lard was diſtilled *per ſe*; the product was waſhed with much warm water and all the watery liquids were united. Acetited lead was then poured in, and a flocculent precipitate fell down, which was collected and dried, and conſiſted of *ſebat of lead*. This was then put into a retort with ſulphuric acid and diſtilled. The liquor in the recipient *had no acid property*, but on the ſurface of the liquor remaining in the retort there floated a melted maſs reſembling fat in appearance, which was carefully collected, and after waſhing was boiled with water. At this heat it diſſolved, and on cooling it depoſited tender needled cryſtals, which were decidedly acid, and which the author conſiders as the pure *ſebacic acid*. To aſcertain whether they were or were not *produced* by the ſulphuric acid, ſome of the ſimply diſtilled liquor of lard was treated with water, filtered and evaporated, and ſome of the ſame cryſtals were ſeparated on cooling, ſhewing therefore that this ſubſtance either exiſted in that ſtate in the freſh lard, or was produced by the mere action of fire, and not by the ſulphuric acid.

This ſebacic acid is without ſmell, has a ſlightly acid taſte, reddens litmus, melts in heat like greaſe, and is much more ſoluble in hot water than in cold, ſo that a hot ſolution at all concentrated, readily concretes by cooling. It is alſo ſoluble largely in alcohol, and cryſtallizes in ſmall needles, but by careful management it may be obtained in the form of broad brilliant plates.

Thenard alſo aſſerts that along with the ſebacic acid much acetous acid is contained in the diſtilled liquor of lard, and that it is this, and not the true ſebacic acid which is given out, when according to Segner's method the liquor is ſaturated with potaſh, evaporated to dryneſs, and decompoſed by ſulphuric acid. In proof of which he aſſerts that in performing the experiment, he obtained under theſe circumſtances, an acid, which, like the acetous, produces a deliqueſcent foliated ſalt with potaſh that has a very pungent taſte, that forms with nitrat of mercury a precipitate which cryſtallizes in plates, and that gives much acetous acid when treated with ſulphuric acid. With regard to the acid obtained by Crell's ſecond proceſs, that is, by treating the fat with alkali and alum, and decompoſing by ſulphuric acid, Thenard aſſerts that on repeating this proceſs he obtained no acetous acid, but only *muriatic*, ſince it precipitates nitrat of ſilver, and forms a cubic ſalt with ſoda, which ſalt, decompoſed ſeparately by ſulphuric acid, gives a penetrating acid vapour, which united with the nitric acid is capable of diſſolving gold. This acid he attributes to employing the common potaſh of commerce, which always contains ſome muriat, for in repeating the experiment with pure potaſh, he obtained no acid except a minute quantity of vinegar.

Such are the experiments of this chemiſt, who is certainly worthy of the higheſt confidence, and they eſtabliſh the fact of there exiſting an inodorous, not eaſily volatile, and cryſtallizable acid ſubſtance in the products of diſtilled fat, to which the term *Sebacic acid* ought probably to be applied.

This acid precipitates the acetite and nitrat of lead, nitrat of ſilver, and acetite and nitrat of mercury; it ſaturates the alkaline baſes, and forms with them ſoluble ſalts; with potaſh it forms a ſalt which does not abſorb moiſture from the air, and is decompoſed by the mineral acids; it does not trouble barytic, lime, or ſtrontian water.

We cannot however admit the explanation given by this ingenious chemiſt of the nature of Crell's volatile acid, to the full extent, without further experiments, though it is ſufficiently probable that it is a very compound liquor, containing a large quantity of acetous acid, perhaps with ſome ſulphureous, and intimately combined with a portion of animal oil.

Every acid procured in any manner from animal fat is probably *formed* by the diſtillation or by the action of the ſulphuric acid, and not

merely *evolved*, since no change in the colour of litmus is produced by the contact of fat, or of water employed to lixiviate it. That the action of heat or sulphuric acid should produce acetous acid from materials which abound in its constituent parts, may readily be conceived, and the history of the pyroligneous, lactic, and some other acids shews how readily the acetous acid undergoes particular modifications by which its proper characters are disguised so as not easily to be detected.

However, till the nature of the pungent volatile acid of fat is fully cleared up, it may be right to give some of the general characters of its saline combinations,[a] though we should hesitate to give them the term of *Sebats*.

When the alkalies are saturated with this acid, and the mixture is evaporated to dryness, redissolved and concentrated, crystals are formed generally in plates and not deliquescent. These are all decomposable by sulphuric acid, and give out vapours, strongly smelling of acetous acid, but with a peculiar pungency. A similar salt is formed with lime, but with magnesia and alumine no crystals can be obtained.

This acid has no action on gold or silver, but dissolves the oxyd of the latter metal. It acts on mercury when repeatedly abstracted from it, but dissolves the white carbonated oxyd with ease in the cold. This salt evaporated to dryness and heated, yields a mercurial sublimate in a very moderate temperature.

Copper dissolves in this acid with ease, and yields small deliquescent crystals. Iron gives an astringent solution, and by evaporation leaves acicular crystals, scarcely deliquescent. Lead, antimony, zinc, and tin, are dissolved with more or less ease.

With some of the metallic solutions this acid produces sensible effects. Added to nitrated silver, a reddish grey precipitate falls down. With nitrated mercury a white precipitate is produced, and even corrosive sublimate is made turbid by this acid. With nitrat of lead, small acicular crystals are deposited which are readily soluble in water, and this latter solution is decomposed by sulphuric acid.

It is obvious that these properties do not belong singly either to the acetous or to the muriatic acid, so that till we have further experiments, we must for the present admit something peculiar in the pungent distilled acid of fat.

SELENITE. See GYPSUM.

SEMI-METAL. A name given by the old chemists to the brittle unmalleable metals. See METAL.

SEMIOPAL. See OPAL.

SENEGAL, *Gum*. See MUCILAGE.

SERPENTINE. *Serpentin*, Germ. *Serpentine*, Broch.

Of this mineral there are the two following subspecies.

1. *Subsp.* Common serpentine.

Its colour is chiefly green of different shades, from pale leek green to olive and blackish green, it also occurs blood red, scarlet red, light crimson, and reddish brown, sometimes, though rarely, brownish yellow. The colours are arranged in dots, clouds, veins, and stripes, and are very much intermixed. It occurs in mass. It is internally dull, or faintly glimmering when mixed with foreign particles. Its fracture is splintery passing into fine grained uneven, also flat conchoidal. Its fragments are indeterminate, blunt-edged. It is usually translucent on the edges; it is soft, easily frangible, and unctuous to the touch. Sp. gr. 2.57—2.7.

It is infusible before the blow-pipe without addition. It appears to admit of considerable variety in its analysis, as appears from its examination by Kirwan and by Bayen.

	Kirwan.		Bayen.
Silex - -	45	—	41
Magnesia -	23	—	35
Alumine -	18	—	10
Iron - -	3	—	3
Water - -	12		
	98		89

A little oxyd of chrome is also said to have been lately found in this mineral.

2. *Subsp.* Noble serpentine.

Its colour is deep leek green, passing into greenish black. It occurs in mass or disseminated. It has a slight greasy or resinous lustre. Its fracture is conchoidal passing into splintery. It is translucent, soft, unctuous to the touch.

Serpentine ranks among the primitive rocks; it very rarely contains beds of other minerals. It is not unfrequently penetrated by veins consisting of calcareous spar, granular limestone, steatite, talc, asbest, garnet, copper, and magnetic iron.

There appear to be two distinct formations of this mineral; the most ancient is in smaller rock masses than the other, and rests upon gra-

[a] Crell.

nite or gneiss; the noble serpentine belongs almost wholly to this formation. The other formation is more recent, is less penetrated by veins, and consists of common serpentine.

The older serpentine is found in Corsica, Italy, and Siberia, and of uncommon beauty at Portsoy in Scotland. The more recent serpentine occurs in Cornwall, at Zöblitz in Saxony, and various other parts of Germany.

This mineral is capable of being readily fashioned in a lathe, and of receiving a very good polish, on which account it is formed into various articles of ornament and use, such as vases, chimney-pieces, &c. many of which are exquisitely beautiful.

SERUM. See Blood.

SHELL.

The shells of marine animals and of all eggs have long been known to consist principally of carbonat of lime, so that when burned they afford a purer quicklime than that procured from most of the common lime-stones, and on the sea-coast shells are often collected in quantity, and employed for making quicklime. All shells therefore effervesce stongly with acids.

But as they are *organized* parts of living animals they have some peculiarities of texture dependent on the mode of their formation, and the earthy part of which they are composed must have been held together by some animal cement, and not merely cohering by simple aggregation. Besides this they mostly contain some portion of phosphat of lime, though in very small quantity compared with the carbonat, and also in comparison with the quantity entering into bone, and the hard parts of land animals.

Mr. Hatchett has given a very valuable memoir on the various species of marine shells, which is useful not only as a register of chemical analyses, but as shewing a distinction between several large classes of shell and elucidating the mode of their formation.*

The method of analysis was so simple that it may be described at first as applying to all. The shell was first immersed in dilute nitric or sometimes in acetous acid, and a solution was effected, without heat, of all the calcareous part, which sometimes required a digestion of a few days. The acid here dissolved both the carbonat and phosphat of lime if present, but would leave the cementing animal membrane, which being of the nature of condensed albumen would remain undissolved. It would also leave untouched any animal charcoal produced by previously roasting the shell in a red heat for a short time, and charring the cementing gluten, which, when not actually in the state of dense membrane, would otherwise dissolve in the acid. To the solution pure ammonia was first added as long as it produced any precipitate, which in these circumstances was phosphat of lime undecomposed. The remaining clear liquor was then fully saturated with carbonat of ammonia, which precipitated all the carbonat of lime, and thus these two calcareous salts were separated, and their quantity ascertained. Sometimes however the substance when of a cellular or porous structure, would contain some slime and argil, too closely adhering to be separated properly, in which case the alumine dissolved along with the calcareous salts would be precipitated by ammonia as well as the phosphat, and would be blended with it. In such cases the mixed precipitate was redissolved in nitric acid and acetite of lead dropped in, which would separate the phosphoric acid in the form of an insoluble phosphat of lead, and the quantity of acid, (and from this, that of lime united to it) could be thus easily estimated.

There are two great classes of marine shells, the testaceous and the crustaceous. The former are by much the most numerous, and include all the marine shell-animals that have not legs and the power of transporting themselves from place to place: the crustaceous shells are those of the lobster, crab, prawn, and such animals as readily shift their place, and who carry the shell merely for protection from external injury, and not also, as in the testaceous, as a place of residence.

The testaceous shells again are divisible into two classes, the *Porcellanous* and those composed of *Nacre* or *Mother of Pearl*, which differ from each other in the quantity of connecting gluten or membrane, and the mode in which it is disposed.

The *Porcellanous shells* are so called because they have an aspect like porcelain, with an enamelled glossy surface, are smooth, hard, and sonorous, and when broken often exhibit a slightly fibrous texture. All the univalve shells, such as whelks, limpets, cowries, and most of the beautiful convoluted shells of tropical countries are of this description.

These shells when exposed to a red heat in a crucible for a quarter of an hour, crackled and lost the colours of their enamelled surface, but did not emit any apparent smoke, nor any smell

* Phil. Trans. vol. 89 and 90.

like burned horn or cartilage. Their figure remained unchanged and they all became of an opake white, retaining part of their original glofs. Thefe diffolved in acids with great effervefcence, and when they had not been previoufly roafted, the folution remained clear, but after roafting, the charred gluten was left untouched. Neither ammonia nor acetited lead difcovered any phofphat, fo that thefe fhells feem to confift entirely of carbonat of lime cemented by a fmall portion of animal gluten.

The *Nacreous Shells* are moftly bivalved, and have a fofter texture, a greater glofs on the inner fide, and often fhew that iridefcent play of colours which is fo particularly beautiful in the mother of pearl. All the oyfter and mufcle fpecies are of this kind. When put in the fire they give a fenfible odour of burned horn with fome fmoke, and exfoliate. When the roafted fhells were immerfed in nitric acid a much greater proportion of charcoal was left than in the former kind. But the moft ftriking difference was with the unburned fhell, for when immerfed in the acid a violent effervefcence and rapid folution took place at firft, but diminifhed gradually, fo that the carbonic acid was only difengaged at intervals. In two days time the whole of the calcareous part was diffolved, but a reticulated feries of membranous layers was left, the outermoft of which was the epidermis or fkin of the natural fhell, fo that the whole formed a tender mafs of membranes ftill retaining the form of the fhell. Each membrane therefore has its correfponding ftratum of calcareous earth interpofed between it and the fucceeding membrane, and hence as every additional ftratum exceeds in extent that which was previoufly formed, the fhell becomes ftronger and thicker in proportion as the animal grows. Hence the vaft thicknefs of fhell in the large full-grown oyfters that yield the mother of pearl. The nitric folution of thefe fhells fhewed no indication of any phofphat, fo that the earth is merely carbonat of lime.

A fecond clafs of fhells has been ftated to be the *Cruftaceous*, fuch as form the covering of the lobfter, crab, &c. Pieces of this fhell were immerfed in nitrous and acetous acids, in each of which they diffolved with moderate effervefcence to a confiderable degree, but in a fhort time the action ceafed and a yellowifh white elaftic cartilage was left, which retained the original form. In the acetous acid the colouring matter alfo remained and was foluble in alcohol. Thefe folutions contain both phofphat and carbonat of lime, and thus it is the prefence of phofphat of lime, though the quantity is comparatively fmall, which diftinguifhes the cruftaceous from all the teftaceous fhells whether porcellanous or of nacre.

It may be added that pearls refemble exactly in chemical compofition, the nacre or mother of pearl; and that egg-fhell bears the ftrongeft affinity with the porcellanous fhells.

SIDERITE.

Is a name given by Bergman to a fuppofed peculiar metallic fubftance which is the principal caufe of the brittlenefs of certain kinds of bar iron. It has fince been difcovered to be phofphat of iron.

SIENITE. *Sienit*. Wern.

This is one of the compound primitive rocks and confifts effentially of cryftals and grains of hornblende imbedded in felfpar. When the felfpar is compact the mafs has a porphyritic character and is often called Sienitic porphyry. Quartz and mica are occafionally found in fienite but in very fmall quantity; in this ftate it is fometimes called granitelle.

Sienite is commonly in mafs, and is rarely either fchiftofe or ftratified. It fometimes contains metallic veins as at Altemberg in Saxony.

SILEX. *Kiefelerde*. Germ.

This earth is generally found in a ftony ftate, and from its forming nearly the entire compofition of *flint*, it has acquired the name of filex or filiceous earth. It is found in equal or perhaps greater purity in rock cryftal and quartz, and in white fand, and on the whole it is probably the moft abundant earth on the face of the globe. Moft of the ftony combinations of filex are remarkable for their hardnefs, and will very readily ftrike fire with fteel.

Silex when pure is white, and perfectly void of tafte and fmell. It is infoluble in water, and is incapable of artificial cryftallization.

It likewife contracts but a very flight union with water when wetted, and is perfectly void of plafticity, fo that after wetting it dries more fpeedily than any other earth. Its fpecific gravity as it exifts in quartz or flint is about 2.6.

It is perfectly infufible by itfelf even in oxygen gas.

This earth is abfolutely infoluble in every acid except the fluoric, unlefs in that ftate of fine divifion in which it exifts at the moment of its feparation from its alkaline folution by acids. Its peculiar habitudes with the fluoric acid have been mentioned under that article.

The fixed alkalies readily diffolve filex by the affiftance of heat, and even in the cold by long digeftion. If flint or fand or any other filiceous

earth in fine powder, be boiled with a solution of caustic potash or soda in which the alkaline portion is about twice the weight of the earth, after the water has entirely evaporated there remains a white puffy mass which perfectly dissolves in warm water into a clear solution. A similar solution is formed by melting the silex in a moderate *red* heat with about three or four times its weight of dry carbonated potash or soda. The mixture effervesces and swells violently during the fusion, owing to the escape of the carbonic acid, and at last settles into a clear glass, which is perfectly soluble in water. A much smaller quantity of alkali, however, is able to dissolve this earth into a perfect glass, in a high heat, but this is not soluble in water unless the alkali is in considerable excess. This solution of *Silicited Alkali*, or Liquor Silicum, as it is sometimes called, has a strong, burning, alkaline taste. When saturated with an acid it becomes turbid, and the earth slowly separates in the form of a spongy flocculent precipitate. If this is taken out without drying, and sulphuric, nitric, or muriatic acid added to it, or if the first solution is at once supersaturated with the acid, the silex is redissolved and the liquor becomes clear. This is much assisted by large dilution with water, for the same proportion of acid will not redissolve the earth when concentrated. If this acid solution of silex is evaporated nearly to dryness, the whole of the silex separates in a gelatinous form from the solution, and becomes as at first equally insoluble in any future portion of acid, so that it may be washed and edulcorated without loss. In this circumstance silex differs from alumine, for the latter is again soluble in acids without further preparation. Silex thus procured is quite white, feels dry, granular, and is perfectly insipid.

There is however a very intimate union between silex and alumine when in solution together, as has been fully explained under the article *Alumine*.

Silex, even when dissolved in an acid or alkali gives no peculiar taste, so that the silicited alkali has simply an alkaline taste, the fluat of silex an acid taste, &c.

Both barytes and strontian in some degree dissolve silex as the alkalies do, but less extensively. Vauquelin mixed 200 parts of strontian with 60 of silex,[a] heated the mixture intensely for an hour in a platina crucible, and produced a grey, sonorous, rifty mass, with only a slight caustic taste. When this was boiled in water, some of it dissolved, though less than if it were pure strontian, and it could not be crystallized. Saturated with nitric acid, it gave by evaporation a copious jelly, which was pure silex.

The same chemist also mixed 150 parts of barytes with 50 of silex, and heated them strongly for an hour in a platina crucible. The resulting mass was of a pale apple green, forming in water a solution of the same colour, and with little taste. This substance was also entirely soluble in most of the acids, and the solution ran into a jelly by evaporation, which was pure silex.

For the effect of alkalies on silex, see the article Glass.

SILICEOUS SCHISTUS. See Keiselschiefer.

SILICITED ALKALI. See the article Silex.

SILK.

This article is introduced in this place on account of a very peculiar salt or crystalline substance obtained from it by the nitric acid.

Silk in its natural state (that is, before it is bleached) contains a kind of yellow resinous matter, which gives its fine golden colour. When raw silk is infused in water, a portion of gummy matter is dissolved, and a light amber coloured liquor is produced. Pure alcohol extracts a much deeper yellow colour, and makes a tincture that loses none of its colour by long exposure to the sun, which bleaches the silk itself.[a]

Nitrous acid acts powerfully on silk in proportion to its concentration. If two drams of this acid are mixed with a pint of alcohol,[b] and silk, either raw or bleached, be immersed in it, and kept in digestion in a moderate warmth for twenty-four hours, the silk becomes of a dull yellowish brown, which after rinsing and washing with soap, and drying, turns to a fine golden yellow, which is very permanent.

But when concentrated nitric acid is distilled off silk, and the remaining liquor duly evaporated, much oxalic acid is obtained, and the residue if evaporated still further, yields along with a little remaining oxalic acid, a quantity of yellow granular crystals, extremely bitter, not acid, and staining the saliva and hands of a very deep yellow not easily removed. If the liquor is previously saturated with potash and evaporated, another yellow silky salt separates, which detonates on coals like common nitre, and appears to be a triple combination of the former bitter substance with nitrat of potash.

The first mentioned granular crystals exa-

[a] Ann. Chim. tom. 29. p. 271.

[a] Beaumé.

[b] Ibid. An. Chim. tom. 17.

mined with a magnifier, appear to be composed of truncated octohedrons.

The above curious substance was discovered by Welter, and is by him called *the bitter principle*, and he supposes it to be generally produced by the action of nitric acid on animal matters, and is perhaps the same substance which causes the bitterness of bile.

It has not been further examined.

SILVANITE. See TELLURIUM.

SILVER. *Silber*, Germ. *Argent*, Fr.

Silver is a metal of a pure white colour, very malleable, soft, fusible at a full red heat, but not oxydable by exposure to the air while melted. It is soluble with ease in nitrous acid, and precipitable from its solution in the form of a white curd by muriatic acid, or any of the neutral muriats.

§ 1. *Ores of Silver*.[a]

Sp. 1. Native Silver. *Gediegen Silber*, Wern. *Argent Natif*, Broch.

Its colour is silvery white, but externally it is often yellowish and brownish, in consequence of being tarnished by sulphureous vapours. It occurs massive, disseminated, in plates, in rounded pieces, also capillary, filiform, reticulated, arborescent and crystallized. The forms of its crystals are,

1. The regular octohedron.
2. The cube.
3. A solid, composed of the two former, and generally represented as a double six-sided pyramid, with truncated summits.

The crystals are usually very small, and grouped together. The surface of the crystals is smooth, that of the plates is drusy, the filiform and capillary varieties are commonly longitudinally striated. Its superficial lustre is metallic, varying from shining to glimmering, according to the smoothness or roughness of the surface. Its fracture is hackly; it acquires a bright shining metallic lustre by friction. It is opake, soft, ductile, flexible but not elastic. Sp. gr. about 10.

The above is the description of pure native silver, it is not unfrequently however alloyed with gold in various proportions; a specimen analysed by Dr. Fordyce afforded 28 per cent. of this latter metal; in this case the colour approaches to that of pale brass, and its specific gravity is greater than that of pure silver. Sometimes also native silver is mixed with a small proportion of copper by which it acquires a tinge of red, and is sensibly harder than when pure.

The most recent of the primitive rocks are those in which native silver principally occurs; it has been found also in stratified mountains. It occurs chiefly in veins accompanied by quartz, heavy spar, and calcareous spar, by various other ores of silver, as well as spathose iron, arsenical pyrites and cobalt, &c.

This ore is abundant in Peru and Mexico, where solid masses of silver have been found weighing 30 or 40 lbs. In Europe it is found most plentifully in Saxony, Bohemia, and Swabia. The mines of Kongsberg in Norway, which used to furnish this ore are now almost entirely exhausted. The Hungarian mines afford a considerable quantity of this ore, and it has been recently discovered in Cornwall. In Asia and Africa silver appears to be less plentiful than gold.

Sp. 2. Silver Amalgam. For an account of this ore see MERCURY, ores of.

Sp. 3. Antimonial Silver. *Spiesglas Silber*, Wern. *Argent Antimonial*, Broch.

Its colour is tin-white, approaching more or less to silver-white; by exposure to the air it is often superficially tarnished, and then exhibits various iridescent colours. It occurs in mass, disseminated, in kidney-shaped masses, or crystallized: the forms of its crystals are the following.

1. The regular hexahedral prism: sometimes the prism is very short so as to become tabular: sometimes its lateral edges are truncated, which gives it a cylindrical appearance.
2. A somewhat oblique four-sided prism, which is often nearly cubical.

The crystals are small and very small; the prisms are longitudinally striated, but all the other faces are smooth. Externally it is glistening, internally it is brilliant, with a metallic lustre. Its fracture is lamellar in one direction, but in others is flat conchoidal. It presents granular concretions of various sizes. It acquires a lustre by friction; is moderately hard and brittle. Sp. gr. 9.44—10.

Before the blowpipe on charcoal this mineral readily enters into fusion, the antimony then flies off in a white vapour, with its peculiar odour, and there remains a globule of silver surrounded with a brownish slag, which colours glass of borax green.

It has been analysed by Selb, Klaproth, Vauquelin and Abich, with the following results.

[a] An. Chim. tom. 29.

[a] Kirwan. Emmerling. Brochant. Jameson. Hauy.

Silver		Antim.		
89	—	11	Selb.	
84	—	14	Klapr.	The fine-grained variety from Wolfach.
76	—	24	Do.	The coarse-grained from Do.
77	—	23	Do.	From Andreasberg.
78	—	22	Vauq.	From Do.
75.25	—	24.75	Abich.	From Do.

It occurs in veins of calcareous spar and heavy spar, accompanied by native silver, galena, and occasionally brown blende, iron pyrites, and grey copper.

It is found at Wittichen and Altwolfach, in the territory of Fürstenberg, at Andreasburg in the Hartz, and at Casalla near Guadalcanal, in Spain.

Sp. 4. Arsenical Silver. *Arsenik Silber*, Germ. *Argent Arsenical*, Broch.

Its colour is tin-white, passing into light lead grey; it is superficially tarnished yellowish or steel grey. It occurs in mass, disseminated, in small globular or kidney-shaped masses, or crystallized: the forms of its crystals are

1. The regular hexahedral prism. Sometimes it is somewhat compressed, or rounded on its lateral edges.

2. An acute six-sided pyramid with the summit truncated.

Internally it is more or less shining with a metallic lustre. Its fracture is small lamellar, either strait or curved. The massive varieties present fine grained distinct concretions; the globular and kidney-shaped are composed of thin curved concentric lamellæ.

It acquires a lustre by friction, is rather soft and brittle.

Before the blowpipe it melts, and the arsenic and antimony are volatilized; there remains behind an impure bead of silver.

A specimen analysed by Klaproth consisted of

Iron - - - - - -	44.25
Arsenic - - - - -	35.
Silver - - - - -	12.75
Antimony - - -	4.
	96.

It occurs in veins of calcareous spar with native arsenic, red and sulphuretted silver ores, galena, and blende.

It is met with at Andreasberg in the Hartz, and Altwolfach in Swabia.

Sp. 5. Carbonated Silver. *Calciform Silver ore*, Kirw. *Luftsaures Silber*, Wid.

Its colour is greyish passing to iron black. It occurs in mass or disseminated. Its lustre is metallic, varying from glimmering to shining. Its fracture is fine-grained uneven, passing into earthy. It acquires a polish by friction. It is soft, not very brittle, and of a high specific gravity.

It is fusible with ease before the blowpipe into a metallic globule. Its component parts, according to Selb, are

72.5	Silver
12.	Carbonic acid
15.5	Oxyd of antimony and a trace of copper
100.	

It was found in 1788 at Altwolfach, in a vein of heavy spar, with native and sulphuretted silver and grey copper.

Sp. 6. Hornsilver. *Hornerz*, Wern. *Argent corné*, Broch.

Of this ore there are the two following subspecies.

1 *Subsp.* Common Hornsilver.

Its colour is pearl-grey, passing on the one hand to milk white, and on the other to lead-grey and violet blue, sometimes, though rarely, it has an olive or leek green tinge. It occurs in mass, disseminated, superficial, in roundish hollow balls, and crystallized in cubes and acicular crystals. The crystals are small and very small, and variously aggregated. Externally it is more or less shining; internally it varies from shining to glistening, and has a resinous lustre. Its fracture is fine-grained uneven, passing into flat conchoidal. It is commonly translucent. It takes a polish by friction. It is very soft, ductile, and flexible when in thin plates. Sp. gr. 4.74—4.80.

When heated on charcoal by the blowpipe, it enters into speedy fusion, at the same time disengaging a disagreeable odour, and affords a globule of metallic silver. The massive horn silver of Saxony has been analysed by Klaproth with the following result.

67.75	Silver
21.	Muriatic acid
6.	Oxyd of Iron
1.75	Alumine
0.25	Sulphuric acid
96.75	

It occurs in veins of quartz, calcareous ſpar, and heavy ſpar, accompanied by native ſilver and other ores of the ſame metal, alſo by iron ochre, galena, malachite, grey copper, and cobalt ochre.

It is ſometimes inviſibly diſperſed through compact limeſtone, forming the alkaline ore of Juſti, and which contains about 2 oz. of muriated ſilver in the quintal.

Hornſilver occurs in conſiderable abundance in the Mexican and Peruvian mines: the Saxon and Bohemian mines, eſpecially thoſe of Johanngeorgenſtadt, uſed to afford great quantities of it, and it is ſtill found there, though by no means ſo plentifully as formerly. It is alſo met with at Schemnitz in Hungary, Chalanches near Allemont in France, and rarely in Cornwall.

2 *Subſp.* Earthy Hornſilver. *Buttermilcherz*, Germ.

Its colour is greeniſh-white, ſlate blue, or reddiſh brown. It occurs in thin ſuperficial cruſts, or diſſeminated. It is without luſtre. Its fracture is fine grained, earthy. It is very ſoft, almoſt friable; is brittle; acquires a ſlight greaſy luſtre by friction; it is ſomewhat unctuous to the touch.

When expoſed to the blowpipe it ſlightly agglutinates, and minute globules of ſilver make their appearance. It conſiſts, according to Klaproth, of

24.64	Silver
8.28	Muriatic acid
67.08	Alumine with a trace of copper
100.	

It occurs at Andreaſberg in the Hartz.

Sp. 6. Red Silver ore. Ruby Silver. *Rothgultigerz*, Wern. *Argent rouge*, Broch.

Its colour is carmine red, light blood red, cochineal red, paſſing into lead-grey, and iron black. It occurs in maſs, diſſeminated, in kidney-ſhaped pieces, in membranes and cryſtallized. Its primitive cryſtalline form is an obtuſe rhomboid, the plane angles of which meaſure 104° 28′ and 75° 32′: it alſo preſents

1. The ſtraight ſix-ſided priſm.
2. A ſix-ſided priſm, truncated by trihedral ſummits with rhomboidal faces.
3. The ſame as the preceding with the lateral edges of the ſummits truncated.
4. The ſame as var. 2 with the point of the ſummit replaced by a triangular plane.
5. The ſame as var. 2 with all the edges truncated.
6. A dodecahedron compoſed of two ſix-ſided pyramids, with ſcalene triangular faces joined baſe to baſe.
7. The preceding, with the pyramids (greatly lengthened) truncated and terminated by ſix-ſided pyramids with triangular faces, or trihedral pyramids with rhomboidal faces.
8. Acicular priſms.

The cryſtals are ſmall and very ſmall, and often occur in druſes. Externally they are more or leſs brightly ſhining with a luſtre between that of the diamond and ſemi-metallic. Internally this mineral is ſhining or glimmering with a ſemi-metallic luſtre. Its fracture is large or ſmall-grained uneven, alſo imperfectly and ſmall conchoidal and rarely imperfectly lamellar. The ſmall light coloured cryſtals are often tranſparent, other varieties are tranſlucent and even opake. When ſcraped it affords a powder of a bright orange-red paſſing into dull crimſon. It is ſoft, moderately brittle and eaſily frangible. Sp. gr. about 5.6.

When expoſed to the blow-pipe it crackles and flies before it becomes red-hot; it then melts with a ſlight efferveſcence emitting a yellow vapour, and at length yielding a globule of ſilver.

The light coloured variety has been analyſed by Klaproth and Vauquelin, with the following reſults,

Klapr.			Vauq.	
60.	62.	—	56.67	Silver
20.3	18.5	—	16.13	Antimony
11.7	11.	—	15.07	Sulphur
8.	8.5	—	0.	Sulphuric acid
0.	0.	—	12.13	Oxygen
100.	100.	—	100.	

It occurs in veins with quartz, calcareous ſpar, brown ſpar, native arſenic, iron pyrites, galena, blende, various ſilver ores, and occaſionally native gold. It is met with at Kremnitz and Felſobanya in Hungary, Freyberg in Saxony, Andreusberg in the Hartz, Joachimſthal in Bohemia, Guadalcanal in Spain, and St. Marie aux Mines in France.

Sp. 7. Sulphurated ſilver ore. Silber glaſerz, *Wern.* Glanzerz. *Lens.* Argent vitreux. *Broch.*

Its colour is deep lead-grey, paſſing into greyiſh black; on the ſurface it is often more or leſs irideſcent. It occurs in maſs, diſſeminated, membranous, capillary, dendritic, corroded or cryſtallized.

1. In double four-ſided pyramids, not un-

frequently truncated on the edges or folid angles.

2. In cubes, either perfect or truncated on the edges or folid angles.

3. In rhomboidal dodecahedrons.

The cryftals are generally fmall and varioufly grouped together. The furface of the cryftals is commonly fmooth, but fometimes drufy. Internally it is fhining or gliftening, with a metallic luftre. Its fracture is fmall grained uneven, fometimes flat conchoidal or imperfectly lamellar. It acquires a polifh by friction. It is foft, confiderably malleable and flexible. Sp. gr. 6.9—7.2.

Before the blow-pipe it melts, parts by degrees with its fulphur, and affords a bead of metallic filver. When expofed to a gentle heat infufficient for its fufion it becomes covered with filaments of metallic filver, as was firft obferved by Schreiber.

It has been analyfed by Klaproth, Sage, and Bergman, with the following refults:

Klapr.		Sage.		Berg.
85	—	84	—	75
15	—	16	—	25
100		100		100

It occurs in veins with quartz, calcareous fpar, heavy fpar, native filver, galena, iron and copper pyrites, and blende.

The moft fplendid fpecimens of this mineral come from Mexico, confifting of groupes of cryftals covered with capillary native filver two or three inches in length; it is alfo found in Peru; in the Saxon, Bohemian, Swabian, and Hungarian mines, at Kongsberg in Norway, Schlangenberg in Siberia, and Allemont in France.

The tenacity of this mineral is fo great, that Auguftus, king of Poland, had fome medals ftruck of it.

Sp. 8. Brittle fulphurated filver. Sproedglaferz. *Wern.* Argent vitreux aigre. *Broch.*

Its colour is iron black, paffing into fteel and lead grey. It occurs in mafs, diffeminated, membranous, and often cryftallized. Its forms are,

1. The ftrait fix-fided prifm with plane or convex terminations. When the prifm is very fhort a fix-fided table is produced: and when the prifm intervening between the convex fummits is fuppreffed the refult is a lenticular cryftal.

2. A fix-fided prifm terminated by fix-fided pyramids which are often deeply truncated.

The tabular cryftals often interfect each other and thus form cellular groups. The cryftals are generally very fmall; their furface is fometimes fmooth, fometimes drufy, the prifms are ftriated longitudinally. The external luftre of this mineral is generally very brightly fhining; internally it varies from gliftering to fhining, with a metallic luftre. Its fracture is fine grained, uneven, paffing into fmall conchoidal. It is foft, brittle, and eafily frangible. Sp. gr. 7.2.

Before the blowpipe, on charcoal, it melts, gives out a white vapour and affords a metallic globule furrounded by fcoriæ, but this globule is not malleable except by fubfequent fufion with nitre and borax. Its contents, according to an analyfis by Klaproth, are,

66.5	Silver
10.	Antimony
5.	Iron
12.	Sulphur
0.5	Copper and arfenic
1.	Earthy impurities
95.	

It occurs in veins accompanied by white filver ore (into which it often paffes) ruby filver, galena, rarely cinnabar and gold. It is met with in Hungary, Tranfilvania, Saxony, Bohemia and Swabia, Norway, France, Siberia, and Peru, but is upon the whole confiderably rarer than the preceding fpecies.

Sp. 9. Bifmuthic filver. Wifmuthifches filber. *Emmerl.* Argent bifmuthifère. *Broch.* Its colour is a light lead grey which becomes deeper by expofure to the air. It occurs generally diffeminated, rarely in mafs. Internally it has a gliftening metallic luftre. Its fracture is fine-grained uneven. It is foft and not very brittle.

When expofed on charcoal to the blowpipe, metallic globules begin foon to ooze out from it; on the addition of borax the metallic parts collect in one mafs, and the flux acquires an amber colour. The metallic button is iridefcent externally, and tin white internally; it is alfo brittle.

The contents of this ore, according to Klaproth, are,

33.	Lead
27.	Bifmuth
15.	Silver
4.3	Iron
0.9	Copper
16.3	Sulphur
96.5	

It is a substance of rare occurrence, having been found only in a mine in the valley of Shapbach in the Black Forest. It is accompanied by quartz, hornstone, and copper pyrites.

Sp. 10. White silver ore. Weissgultigerz, *Wern.* Mine d'argent blanche. *Broch.*

Its colour is light lead-grey, passing sometimes to steel-grey. It occurs in mass and disseminated. Internally it has a glistening metallic lustre. Its fracture is even, passing into fine-grained uneven; when this latter is the case it is generally in a state of transition to the brittle sulphurated silver (Sp. 8) sometimes it has a tendency to the fibrous texture, and appears to be passing into plumose antimony. It gives a shining streak; is soft, not very brittle; easily frangible. Sp. gr. 5.32.

Before the blowpipe it in part evaporates, leaving on the charcoal a silver bead surrounded with yellow powder. Both the light and dark coloured varieties have been analysed by Klaproth with the following results:

Light		Dark	
48.06	—	41.	Lead
20.4	—	9.25	Silver
7.88	—	21.5	Antimony
2.25	—	1.75	Iron
12.25	—	22.	Sulphur
7.	—	1.	Alumine
0.25	—	0.75	Silex
98.09		97.25	

It is procured from the mine Himmelfurst near Freyberg, where it occurs in veins accompanied by galena, red silver, brittle sulphurated silver, plumose antimony, brown spar, and calcareous spar.

Sp. 11. Grey silver ore. Graugultigerz. *Klapr.*

This species has lately been introduced by Klaproth among the silver ores as differing essentially from the white silver ore with which it is confounded by the Hungarian miners. It occurs in mass or disseminated through white quartz at Kremnitz in Hungary, and appears to be only a variety of Fahlerz or grey copper. It consists, according to Klaproth, of,

14.97	Silver
31.36	Copper
34.09	Antimony
3.3	Iron
11.5	Sulphur
0.3	Alumine
95.52	

Sp. 12. Black silver ore. Schwarzgultigerz. *Wern.*

Its colour is iron-black, passing into steel-grey. It occurs massive, disseminated, and crystallized in trihedral pyramids bevilled on the edges and solid angles. The crystals are middle-sized and small. Internally it is shining with a metallic lustre. Its fracture is small conchoidal passing into uneven. It is moderately hard, brittle, and easily frangible.

It has not been analysed, and appears to be a mere variety of the preceding.

Sp. 13. Sooty silver ore. Silberschwarze. *Wern.* Argent noir. *Broch.*

Its colour is bluish-black passing into lead-grey. It occurs in mass, disseminated, carious, superficial or in rounded pieces. Its consistence is between solid and friable. It is dull but acquires a metallic lustre by friction. It stains in a slight degree, is soft, and somewhat malleable.

When exposed to the blowpipe it melts easily into a slag, and by continuing the heat a portion is volatilized and there remains behind a dull looking globule of silver.

It has not been analyzed but is supposed to be a mixture of sulphurated and horn silver in a state of semi-decomposition.

It occurs in veins accompanied by heavy spar, native, sulphurated, and horn silver ores, iron ochre, malachite, and galena. It is met with at Schemnitz and Kremnitz in Hungary, Joachimsthal in Bohemia, Freyberg in Saxony, and Allemont in France.

§. 2. *Assay and Analysis of Ores.*

The *Assay* of these ores having in view merely to ascertain the proportion of silver which they contain, is generally conducted in the dry way. For this purpose the ore being roasted and pulverized is to be mixed with litharge, in proportion to the earthy contents of the ore, and hastily vitrified; the mass thus produced being pulverized and mixed with black flux is to be fused in a crucible with a sufficient heat; the consequence will be that the lead of the litharge being revived will collect in a button at the bottom of the crucible, carrying with it the whole of the silver with some of the other metals that may happen to be present; this button together with such a quantity of pure lead as may be requisite, is to be subjected to cupellation, by which all the base metals are scorified, the silver remaining behind in a state of purity, or at most only combined with the gold which many of the ores of silver contain in a small proportion, and which may be separated from it

by methods which have been already described when treating of that metal and of the art of ASSAYING. Two or more assays of the same ore must be undertaken, and no dependence ought to be placed on the result except they very nearly correspond.

The *analysis* of an ore differs from its assay in this, namely, that its object is to ascertain not one alone, but the whole of its ingredients, and therefore must be undertaken in the moist way. For the most numerous and best analyses of the various ores of silver we are indebted to Klaproth, and as most of these are models of chemical skill and dexterity, we shall relate the particulars of them, with such remarks as the subject may require.

1. *Hornsilver*.[c] Two hundred grains of a massive variety of this mineral were treated with thrice their weight of pure nitric acid, but no perceptible action took place, either in the cold or at a boiling heat, except that a little iron ochre was separated. The solution being decanted and mixed with ammonia, an additional portion of oxyd of iron was thrown down; the supernatant liquor became opalescent on mixture with muriatic acid, but no precipitate was deposited; hence it was manifest that the muriated silver in the ore was not mixed with any in the metallic or sulphurated state, otherwise it would have been taken up by the nitric acid and have afforded a precipitate with the muriatic acid. The insoluble part of the ore was then treated with twice its weight of salt of tartar, and yielded 133 grains of reguline silver. On this preliminary information the following analysis was founded.

a. Two hundred grains of the ore were mixed with 600 grains of caustic potash, and fused in a glass retort. After refrigeration, the neck of the retort being broken off, the fused mas was softened with hot water, and every thing soluble in this menstruum being taken up by it, the liquor was obtained clear by filtration.

b. The insoluble portion was then digested in nitric acid, by which the greater part of it was taken up.

c. The part insoluble in nitric acid was digested in aqua regia, and there remained undissolved a few grains of a white colour, which proved to be muriat of silver, with a little of the earthy matrix of the ore. This muriat of silver afforded (probably by fusion with potash) 2 grs. of pure silver. The nitro-muriatic solution being decomposed by ammonia, gave 7 grains of oxyd of iron.

d. To the nitrous solution (*b*) was added a solution of common salt, and the muriated silver thus obtained afforded by fusion with soda, 134½ grains of pure silver. The fluid remaining after the separation of the muriated silver, gave by saturation with ammonia 5 grains of oxyd of iron.

e. The alkaline aqueous solution (*a*) being saturated with distilled vinegar, there precipitated 3½ grains of alumine; which being separated the liquor was evaporated to dryness, and the product then digested in alcohol, by which the acetite of potash was taken up, leaving the muriated potash behind; which latter by solution in water, evaporation, and cooling, yielded 117½ grains of muriated potash.

f. The muriated potash being again dissolved in water, there was added muriated barytes, by which a precipitate of about 3 grains of sulphat of barytes was obtained. This is considered by Klaproth as indicative of 1½ grains of sulphated potash, which reduces the amount of muriated potash to 116 grains, in which the muriatic acid amounts to 42 grains.

From these results the contents of the ore are stated at *per cent*.

67.75	Silver
21.	Muriatic acid
6.	Oxyd of iron
1.75	Alumine
0.25	Sulphuric acid
96.75	

The mode of analysis here adopted appears to be perfectly satisfactory, but there seem to be a few oversights in stating the results.

1. The silver is a little under-rated, its amount, according to processes *c*. and *d*. being 136.5 or 68.25 *per cent*.

2. There is no notice of the oxygen, which forms an essential part of muriated silver, and in consequence of this omission, the muriatic acid is probably estimated much too high. The amount of the silver may be considered as ascertained with the most exactness as it was actually reduced to the reguline state. Assuming this therefore as the basis of our calculations, and that 100 parts of muriated silver consist of 75.24 silver, 8.16 oxygen, and 16.6 acid, it follows that 136.5 of silver require, in order to be converted into muriat of silver, 14.72 of oxygen and 30.04 of acid. But 30.04 of muriatic acid, when saturated with potash, would afford only about 84 of muriated potash, instead of 116, as

[c] Klap. Annalyt. Ess. I. p. 116.

obtained by process *f*. It may be added, as a further proof of the amount of this salt being erroneously stated, that 42 grains of muriatic acid (contained in 116 grains of muriated pot-ash) indicate 253 grains of muriated silver, which is impossible, the whole amount of the ore being only 200 grains. It is probable therefore that the following corrected statement of the contents of this ore is nearer the truth than that quoted above, viz.

68.25	Silver
7.36	Oxygen
15.02	Muriatic acid
6.	Oxyd of iron
1.75	Alumine
0.5	Sulphuric acid
98.88	

2. *Red Silver.*[d] This ore was analysed by Klaproth in the following manner.

a. Five hundred grains being very finely pulverized, were digested for several hours at a low heat, with 6 times their weight of strong nitric acid and water: a further quantity of water was then added, and the liquor was made to boil. The nitrous solution being poured off, the undissolved residue was treated with an equal portion of acid as at first, and managed in the same manner: the whole was then thrown on the filter, and the insoluble matter was well edulcorated.

b. The two nitrous solutions with the washings being added together, were reduced by evaporation to ⅛ of their bulk, and the remaining liquor deposited by cooling a considerable quantity of greyish-white crystals of sulphated silver. The nature of these crystals being ascertained, some water was added to the supernatant liquor, and by a gentle heat the whole was redissolved. The solution was then combined with muriatic acid as long as any precipitate was produced, and by this method muriated silver was obtained, which, when edulcorated and dried, weighed 391.5 grains.

c. The fluid from which the above precipitate had been obtained, was then reduced to a small bulk by distillation, in consequence of which it became turbid and deposited 1 grain more of muriated silver: nothing now remained in the liquor except some sulphuric acid.

d. The portion insoluble by nitric acid (*a*) weighed 202 grains, and was digested in aqua regia, consisting of 5 parts muriatic acid and 1 of nitric. After the action of this menstruum there remained 65 grains undissolved, which residue after being duly washed and dried, was exposed to a gentle heat, in consequence of which the sulphur burnt off, leaving behind 6¼ grains of muriated silver.

e. The nitro-muriatic solution after being concentrated by evaporation, was poured into a large quantity of water, upon which a white precipitate fell down, weighing, when dried, 133 grains. This was oxyd of antimony, entirely unmixed with the smallest portion of arsenic. When fused in a covered crucible with tartar, a button of reguline antimony was produced, and this when heated on a test before the bellows, was volatilized, leaving behind 0.5 grains of silver.

f. The residues of the nitro-muriatic solution (*e*) and of the nitric solution (*c*), were mixed together and distilled till dense white vapours began to rise; this concentrated fluid was then diluted with water, and muriated barytes was added as long as any decomposition took place. The sulphat of barytes thus obtained amounted to 194 grains.

In this analysis the muriat of silver obtained amounted to 399 grains, which, being reduced to the metallic state furnished, together with the half grain of silver contained in the antimony, exactly 300 grains of pure silver, a result which was confirmed by two assays of this ore on the cupel, each of which yielded 30 *per cent.* of silver.

In order to ascertain the quantity of antimony contained in the 132 grains of white oxyd, 100 grains of reguline antimony were digested in warm muriatic acid, to which nitric acid was added drop by drop, till the whole of the metal was dissolved. This solution being concentrated by evaporation and then poured into water, afforded 130 grains of white oxyd. Hence the above 132 grains indicate 101.5 of reguline antimony.

With respect to the sulphuric acid which made its appearance in this analysis, it is affirmed by Klaproth to have pre-existed, at least for the most part, in the ore, and not to have been produced by the action of the nitric acid upon the sulphur, for the following reasons. In the first place the quantity of nitrous gas disengaged during the action of the nitric acid on the ore is by no means sufficient to account for the production of so large a quantity of sulphuric acid. Secondly, some finely pulverized red silver ore being digested with strong muriatic acid, the solution was found to contain not only antimony

[d] Klap. Analyt. Ess. 1. 127.

and filver but alfo fulphuric acid. Now as muriatic acid is incapable of acidifying fulphur it follows that the above mentioned acid muft have pre-exifted in the ore. This is further confirmed by an obfervation of Henkel's that the filver may be extracted from the red ore merely by fucceffive digeftions in muriatic acid, which could not have happened without the prefence of fulphuric acid likewife. We fhall return to the confideration of this queftion prefently.

The analyfis of this ore by Vauquelin[e] was thus conducted.

a. 100 parts of the ore finely pulverized were treated with 400 parts of nitric acid, and 200 of water: the colour of the mineral became by degrees grey and then paffed into white. During the whole of this change there was no perceptible difengagement of nitrous gas, whence it may be concluded, fays the author, that the ingredients of the ore were already fufficiently oxygenated to diffolve in nitric acid. After a gentle ebullition, the whole was thrown on the filter, and the infoluble portion after edulcoration weighed 42.06

b. The infoluble portion was digefted in ftrong muriatic acid, by which its colour became yellow, and its amount was reduced to 14.66. Being then laid on a hot coal it burnt entirely with a blue flame and all the other characters of fulphur. The fulphur of the ore therefore may be reckoned at 14.66

c. The muriatic folution being poured into a large quantity of water, depofited a white flocculent precipitate of oxyd of antimony, weighing 21.25 and compofed, according to Vauquelin, of 16.13 antimony, and 12.12 oxygen.

d. The nitrous folution (*a*) was mixed with muriatic acid, and furnifhed 72.66 of muriated filver, equivalent, according to Bergman, to 56.67 of metal.

In this analyfis by Vauquelin there is no mention made of fulphuric acid which was found fo abundantly by Klaproth: and in order to bring this matter more compleatly to an iffue, 100 parts of the ore were digefted with a folution of cauftic potafh. As foon as the two fubftances came into contact, the colour of the ore changed firft to grey, and prefently to a deep black; 66. parts remaining undiffolved. Thefe were then treated with dilute nitric acid at a gentle heat, upon which a difengagement of nitrous gas took place, and the undiffolved matter amounted only to 8. parts, and was fulphur. The nitric folution on the addition of muriatic acid afforded 70 of muriated filver. The alkaline folution, which was perfectly clear and colourlefs, gave, when treated with muriatic acid, 32. of antimonial kermes: after the feparation of this, the refidual liquor was mixed with muriat of barytes without any precipitate being formed: hence it contained no fulphuric acid. Indeed Klaproth himfelf at the conclufion of his differtation on this fubject, is difpofed to think that the fulphuric acid, as fuch, does not exift in the ore, but that the whole of the fulphur is in the ftate of oxyd, and by the action of the menftrua employed in the decompofition of the ore, the whole of the oxygen unites with part of the fulphur, converting it into fulphuric acid, and leaving the remainder of the fulphur compleatly deoxygenated. But we do not fee how this can be the cafe: befides it is obvious that the filver at leaft muft be in the ftate of oxyd, fince it diffolves in nitric acid without producing any nitrous gas. If it were not therefore for the circumftance that the ore when treated with fimple muriatic acid gives out fulphuric acid, we fhould be difpofed to believe that the ore contains no fulphuric acid, and that the oxygen is combined not with the fulphur but with the metal.

3. *Sulphurated Silver.*

The analyfis of this ore by Klaproth is very fimple. After being cut into fhreds, it was digefted with 8 times its weight of nitric acid diluted with half its bulk of water. When the action of the acid had ceafed it was poured off, and the infoluble refidue being dried and weighed, was burnt on a teft: the fulphur was thus driven off, and there remained behind a little fulphat of filver, which was then reduced to the metallic ftate by fufion with carbonated foda. The nitrous folution, on the addition of common falt, gave a precipitate of muriated filver, and nothing elfe remained in the liquor except a minute portion of fulphuric acid formed no doubt by the action of the nitric acid on the fulphur of the ore. To confirm this analyfis two affays were made in the dry way, and the quantity of filver thus obtained not only correfponded precifely in each of them, but alfo with that procured in the analyfis.

4. *Brittle Sulphurated Silver.*

a. 100 parts of this ore when levigated were boiled in dilute nitric acid till the original black colour of the ore had changed to a greyifh yellow.

[e] Journ. des Mines, No. 17. p. 1.

b. To the nitrous solution was added a solution of muriated soda by which a precipitate of 84.75 grs. of muriated silver was obtained.

c. The remaining filtered solution was tested with sulphat of soda, but no precipitation took place, thus showing the absence of lead. An excess of caustic ammonia was then added which threw down a grey precipitate weighing 5 grs. This when heated exhaled a slight arsenical odour, and being dissolved in nitric acid afforded a deep blue precipitate with prussiat of potash: thus showing it to be oxyd of iron with a little arsenic.

d. The ammoniacal solution which had a light blue colour, was slightly supersaturated with sulphuric acid, a polished piece of iron being then inserted was tinged with copper, but in so small a quantity as not to be ascertained.

e. The portion of the ore *(a.)* insoluble in nitric acid was digested in nitro-muriatic acid, and the part not taken up by this menstruum amounted to 13 grs. of which 12 were burnt off on a test, and were sulphur; the remainder was silex.

f. The nitro-muriatic solution being poured into water deposited 13 grs. of oxyd of antimony.

5. *White silver ore.*

a. 400 grs. of this being pulverized, were mixed with 4 oz. of strong nitric acid, and 2 oz. of water. After the menstruum had ceased to act it was poured off and replaced by 2 oz. of nitric acid, to which, after being digested for some time, were added 8 oz. of water, and the whole was boiled. The undissolved residue after edulcoration weighed 326 grs.

b. To the nitrous solution was added common salt by which muriated silver was immediately precipitated, and after a few hours were also deposited crystals of muriated lead. The mixed precipitate was boiled with much water, by which the muriated lead was dissolved, and the muriated silver obtained pure; from this by fusion with soda were obtained 81.5 grs. of silver.

c. The two solutions being mixed together, there was added pure ammonia to saturation, which threw down a light brown sediment, weighing 40 grains. This was redissolved in nitric acid, and by the addition first of prussiated potash, and then of soda, was separated into 12 grs. oxyd of iron and 28 alumine.

d. The undissolved residue (*a*) was boiled in repeated portions of muriatic acid, and at length there remained only 51 grs. which when ignited proved to be 49 grs. of sulphur, and 2 grs. of a residue, half of which was silex and the other part being soluble in muriatic acid, was added to the other muriatic solution.

e. The muriatic solution was repeatedly evaporated till it ceased to deposit crystals. These being collected, and mixed with twice their weight of black flux, were reduced in a lined crucible, and afforded 160¾ grs. of lead. This lead when cupelled emitted a few antimonial vapours, and left behind ¼ of a grain of silver.

f. The muriatic solution, after the muriat of lead had been separated, was poured into water and deposited a white oxyd of antimony, which being mixed with soap and black flux was reduced by fusion to the metallic state. In this process however a slight portion of the antimony was volatilized; what remained weighed 31.5 grs.

6. *Grey silver ore.*

a. 300 grs. of this were pulverized and digested with four times their weight of nitric acid; when this had ceased to act it was poured off and replaced by another equal quantity of the same acid. The undissolved portion was of a greyish yellow colour, and weighed 188 grs.

b. To the bright green nitric solution was added a solution of muriated soda, and the precipitate thus obtained afforded by fusion with soda 31.5 grs. of silver.

c. The silver being thus separated, sulphat of soda was added, but without occasioning any precipitate, therefore the liquor contained no lead.

d. Caustic ammonia was then added to supersaturation, upon which a brownish red sediment fell down, which when ignited weighed 9.25 grs. By digestion in nitric acid it dissolved, with the exception of 0.5 gr. of silex. Prussiat of potash threw down from the solution a deep blue precipitate, after which 1.5 gr. of alumine was obtained by means of soda. Hence the oxyd of iron amounted to 7.25 grs.

e. The blue ammoniacal solution was now supersaturated with sulphuric acid, and a piece of polished iron procured from it 69 grs. of copper.

f. The insoluble portion (*a*) was boiled with six times its weight of muriatic acid, which being poured off when its action had ceased, there remained 105.5 grs. still undissolved.

g. The muriatic solution being concentrated by evaporation, deposited a little muriat of silver, from which 0.25 gr. of metal was obtained. The fluid being then poured into

water afforded 97.25 grs. of antimonial oxyd, equivalent to 75 grs. of metal.

h. The residue (*f*) insoluble in muriatic acid, weighing 105.5 grs. was ignited, and 25.25 grs. of sulphur were thus burnt off. The remaining silex was then fused with four times its weight of black flux, and afterwards dissolved in water, leaving behind it 0.75 gr. of silver. Hence the amount of silex was =79.5 grs.

7. *Bismuthic Silver ore.*

Having previously ascertained by roasting that this ore contained sulphur but no arsenic, and having obtained by cupellation from the roasted ore 11.16 per cent. of silver, the analysis was thus conducted.

a. 300 grs. were digested first with 3 oz. of nitric acid and 1 oz. of water, and afterwards with 1 oz. of the same acid and ½oz. of water: 178 grs. remained undissolved.

b. The nitric solution being concentrated to the crystallizing point was poured into a large quantity of water, a white powder was thus obtained which proved to be oxyd of bismuth, and weighed 44.5 grs.

c. To the filtered liquor was added muriatic acid as long as any turbidness ensued. The precipitate thus procured was then digested in moderately strong nitric acid, and there remained behind 46. grs. of muriated silver.

d. The last mentioned nitrous solution was poured into water and afforded 32 grs. of oxyd of bismuth, which added to the other made up 76.5 grs. equivalent to 62.2 grs. of metallic bismuth.

e. The nitro-muriatic liquor was then evaporated till crystals of muriated lead began to form; sulphuric acid was then added, and evaporation was carried on till the whole became thick. The sulphat of lead thus obtained when washed and dried weighed 19 grs.

f. The residue of the fluid was now supersaturated with ammonia, which threw down oxyd of iron, which, after being rendered magnetic by roasting with wax in a covered crucible, weighed 14 grs.

g. Into the blue ammoniacal liquor was placed a bar of clean iron, by which 2 grs. of copper were precipitated.

h. The insoluble residue (*a*) being ignited lost 37.5 grs. which were sulphur. The remainder was boiled first with 3 oz. and afterwards with 1.5 oz. of muriatic acid. This solution being evaporated to the crystallizing point and then mixed with sulphuric acid, deposited by evaporation 89. grs. of sulphated lead, which added to the 19. grs. in process (*e*) is equivalent to 76. grs of reguline lead.

i. The residue, insoluble in muriatic acid consisted merely of the quartzose matrix of the ore, and weighed after ignition 70. grs.

§ 3. *Reduction of Ores.*

Although it appears from the account which we have given of the ores of this metal that many of them when pure are very rich and mixed with a small portion comparatively of other metals, yet the value of silver is so much greater than that of any other, excepting gold, as to make it well worth while to work as silver ores, those which contain only a very minute quantity of this precious metal. Hence it is that in practice the silver ores contain a much larger proportion of foreign matters than those of the inferior metals do, and will allow of being subjected with profit to much more expensive processes than can be employed for the reduction of the others.

All the different methods that are used may be arranged under two heads, namely, 1. The method by fusion. 2. That by amalgamation. We shall begin by describing the most simple of the former, and proceed to the more complex.

Reduction by Fusion.

1. We have already mentioned under the article Lead, that galena, or the native sulphuret of this metal, generally contains a portion of silver. Not unfrequently this latter ingredient is in sufficient plenty to make its separation from the lead a profitable undertaking. The smallest proportion of silver which it is worth while to be at the trouble of extracting cannot be laid down with much accuracy, depending as it does on the market price of silver, of lead, of fuel, of labour, &c. We apprehend that in this country it will scarcely answer with any lead that contains less than 12 oz. in the ton. It is obvious that the richer the lead is in silver the better is it able to pay for any extraordinary care in its preparation, and of the more consequence it becomes to extract from the ore as great a quantity of metal as possible, even at an expence which mere lead would be unable to support.

Argentiferous galena when raised from the mine, is generally mixed with a larger proportion of stony matrix than common galena, because in consequence of the silver which it contains it is worth the miner's while to work much smaller and poorer veins of ore, than if

the profit was to depend on the lead alone. It may be further observed that the silver is for the most part accompanied by antimony which hardens the lead and greatly deteriorates its quality except this ingredient is driven off; now the only economical method of getting rid of it is by the very same process by which the silver is obtained; thus a double advantage ensues, the silver is separated from the lead, and the lead by being at the same time deprived of the antimony, is rendered softer and more marketable.

The proportion of silver contained in galena is extremely variable. The richest that we have heard of was formerly dug in Brunghill Moor in the district of Craven in Yorkshire; it contained about 230 oz. of silver per ton of lead. The Cardiganshire mines, near Plinlimmon, in the reign of Charles I. afforded a lead which yielded 80 oz. per ton. The Durham and Westmoreland leads, by which the Northumberland refineries are at present supplied, yield upon the average about 17 oz. of silver per ton. The large refinery at Poullaouen in Brittany, is supplied with lead of various qualities, the average produce of which, exceeds 39 oz. per ton. Of the different processes carried on at this establishment, an excellent account has been published,[f] of which we shall give an abridgement, noticing at the same time, those particulars in which it is inferior to the best English practice.

The ore, which is very largely mixed with gangue, is first dressed by hand and afterwards stamped and washed by means of the common apparatus. Being thus brought to the consistence of sand, and containing, besides argentiferous galena, a small portion of blende, of iron pyrites and of the earthy gangue, it is delivered to the smelter. The reduction of the ore is effected at two processes; the first, which is roasting, is performed in a common reverberatory. Here it is exposed at first to a bright red heat, which however is gradually diminished as the sulphur is volatilized for fear of bringing the mass to a state of fusion. In about an hour's time the surface of the ore begins to clot, which is the signal for turning it over with long spades, in order to expose fresh surfaces to the action of the heat. If this business is duly performed, in about five or six hours the sulphureous vapours will have nearly ceased, and in consequence, the flame playing on the surface of the ore will have changed from blue to reddish white, thus shewing that the roasting is compleat. The second process commences by throwing upon the surface of the half-oxydated ore a few spadefuls of charcoal, and pushing the fire vigourously; by this treatment, globules of melted lead begin to exude and collect in a mass in the cavity or bason of the furnace, with the unreduced part floating on its surface. In about an hour, or an hour and a half, a sufficient quantity of melted metal is collected for the first running; upon which a little quicklime is thrown in, which coagulates the fluid scoriæ, and these being raked to the side, the bason is pierced with an iron bar, and discharges the melted metal which it contains into a hemispherical reservoir adjoining the furnace. The channel formed by the bar is now closed with clay, and in about an hour after the first running a sufficient quantity of metal is collected in the bason for a second, which is performed exactly in the same manner as the first. In proportion as the scoriæ become more and more poor, a greater heat is required to keep them sufficiently fluid for the globules of reduced lead to fall readily through, so that after from eight to nine runnings have been taken it is not worth while to expend any further quantity of fuel upon them; they are accordingly removed from the furnace, and another charge of fresh ore is immediately thrown in. The lead after it has flowed from the furnace into the reservoir is covered with pulverized charcoal, and remains untouched for some time, that the scoriæ and other impurities may rise to its surface; when this has taken place, the substances floating on the metal are skimmed off, and its surface is covered with sawdust and small chips of wood, to which is added, by small pieces at a time, about 1½ lb. of rosin; in the mean time the melted metal is stirred about vigorously to compleat its purification; as soon as the flame declines, the lead is removed with iron ladles, and poured into moulds. A single charge of ore weighs about 26 quintals and yields about 13½ quintals of metal and more than 7 quintals of scoriæ, containing 30 per cent. of metal, which are reduced by a subsequent process in a blast furnace.

The lead being thus extracted from the ore, the next thing to be done is to obtain the silver in a separate state which is diffused through the whole mass of lead; for this purpose cupellation must be had recourse to. In the article Assay we have noticed the theory of cupellation, and the method of performing it in the

[f] Beaunier & Gallois in Journ. des Mines, No. 93.

ſmall way; we ſhall here therefore only particularize the circumſtances in which cupellation in the great, or *refining* as it is uſually denominated, differs from the former. It is performed in a reverberatory furnace, the floor of which is horizontal, and is lined with a mixture of wood-aſhes and ſand, well beaten and formed into a ſhallow baſon called the cupel. At one ſide of the cupel, and forming a right angle with the flue by which the flame from the fire-place enters the cavity of the furnace, is an aperture, through which the lead flows when converted into litharge, and oppoſite to this is another aperture for the admiſſion of a blaſt of air. In the top of the furnace is a circular aperture, juſt above, and correſponding in ſize with the cupel, which may be cloſed by a frame-work of iron filled up with bricks. The furnace being ready the cupel is lined with hay, and charged with about 177 quintals of lead in bars or pigs, by means of the circular aperture juſt mentioned; the cover is then put on, and the fire is lighted. In about ſix hours the lead is entirely melted and brought to a full-red heat, at which time a blaſt of air is introduced by a metallic pipe, and ſo directed as to ſtrike upon the ſurface of the melted lead; the aſhes of the hay and other impurities are alſo removed by means of a wooden rake thruſt in at the aperture for the litharge. When the blaſt has been in action for half an hour or more, the ſurface of the lead is covered with a thick cruſt of oxyd, which being ſcraped off is preſently ſucceeded by another, and it is not till the ſurface has been cleared five or ſix times, that the true litharge makes its appearance. As ſoon as this takes place the temperature is raiſed nearly to a cherry-red, and by the action of the blaſt, the litharge with a little occaſional aſſiſtance from the workman is made to flow out of the furnace by the aperture already mentioned. A conſiderable portion of lead is alſo volatilized by the intenſe heat, ſo that the interior of the furnace is filled with vapours to ſuch a degree, that none but an experienced eye can diſcern what is going on in the cupel. In about 38 or 40 hours after lighting the fire, the contents of the cupel are diminiſhed to about 6 quintals, and the litharge which now comes over is kept ſeparate from the reſt on account of a ſmall quantity of ſilver which it contains. After a time the litharge ceaſes to flow, and the ſurface of the metal in the cupel appears to be covered only by a thin pellicle: by degrees it becomes convex at the edges, the pellicle breaks up, and the ſurface of the metal appears quite bright. The fire is now damped, the blaſt is turned off, and an aperture in the furnace, which had before been ſtopped with clay is opened to give admiſſion to a tin-plate tube, through which a ſtream of water is poured into the cupel in order to cool the metal rapidly, and thus prevent it from ſpirting, which it would do if left to itſelf at the moment of congelation.

The cake of metal thus procured is not however perfectly pure ſilver, and requires a ſecond cupellation at a higher heat to free it entirely from the lead with which it is mixed. The cupel made uſe of on this occaſion is a moveable one, and not capable of holding above 700 or 800 oz. It is placed in a ſmall reverberatory, and after being heated about three hours, is charged with ſilver of the firſt cupellation. A proper working heat is kept up for about four or five hours after the fuſion of the ſilver, at the end of which time the refining is uſually compleated; the contents of the cupel are then diſcharged into a mould, and thus formed into ingots. The loſs of lead by volatilization during the refining amounts to about 8 per cent.

The demand for litharge is very ſmall in compariſon to the quantity produced, the greater part of it therefore muſt be reconverted into lead; for this purpoſe it is returned to the reverberatory, and treated in the ſame manner as the ore, by which the greater part of it is converted into lead of the beſt quality, being conſiderably ſofter than when it has merely undergone the common reduction. The ſcoriæ remaining after reduction of the ore and the litharge, together with the old cupels, the metallic ſoot collected in the chimney of the furnace, &c. are laſtly treated in a common blaſt furnace, and made to yield a conſiderable portion of the lead that they contain, after which the reſidual ſlag is thrown away.

The practice in the Engliſh refineries differs from that juſt deſcribed in ſome particulars, which we ſhall proceed to notice.[b]

The furnace reſembles the common reverberatory except that its area is perforated with a large oval hole for the reception of the cupel. The cupel itſelf is thus formed: ſix parts of well-burnt bone aſhes and one part of good fern aſhes are mixed together and moiſtened to a proper conſiſtence; of this a quantity is ſtrewed to the depth of about two inches, in an iron frame, conſiſting of a raiſed elliptical rim with five broad bars rivetted to its bottom, ſo as

[b] Sadler in Nich. Phil. Journ. 8vo. vol. xx. p. 1.

to occupy nearly one-half of its area. By means of a wooden beater the ashes are rammed down very close, especially between the bars of the frame, as it lies on a flat floor, more ashes are then added and beaten carefully in till the frame is quite full. A cavity is then formed in the test by a sharp spade, for the purpose of containing the melted metal, and at one end of the frame a semi-elliptical hole is cut quite through the ashes to form a passage for the litharge, in forming which, care must be taken to leave a breast of sufficient solidity and thickness between this hole and the cavity; two shallow channels are then made across the breast through which the litharge may flow down the hole, and so escape out of the furnace. The test being thus prepared is placed in the furnace, so as to occupy and cover the large oval hole in its bottom, and is fixed firmly in its place with tempered clay. A gentle fire is now to be lighted and gradually increased till the test is red hot and ceases to emit steam from its under side: an aperture in the furnace called the feeding hole, is then opened, and the test is charged with melted lead, the fire is raised, the blast from a pair of double bellows is let on, and the cupellation commences. One of the channels through the breast of the cupel is deepened from time to time, to allow a free passage for the litharge; and fresh charges of melted lead are poured into the cupel, till the gutter is so worn as not to allow the cupel to contain more than an inch in depth of metal. The blast is then taken off, the old gutter compleatly filled up with moistened ashes, and the bason of the cupel replenished with melted lead: the blast being again turned on, the litharge is directed into the channel at the other end of the breast, and the operation goes on as at first, till this gutter is likewise worn down, and the test contains no more than about 60 lbs. of metal which is let out into an iron pot, and thus this first part of the process is compleated. The second cupellation is similar to the former, and not materially different from the French mode except that when the silver is compleatly refined, it is allowed to cool gradually, instead of having water poured upon it, and the consequence is, that while congealing, a portion of silver spirts out, and is probably lost.

2. As an example of the method of treating the proper ores of silver, we shall give an abstract of the processes employed at Allemont in France, under the direction of M. Schreiber.* The ores where rough are chiefly native silver, and the sulphuret of silver, mixed with a little arsenical cobalt, with pyrites, with iron ochre, with clay, calcareous spar, and other earthy minerals. Much of the silver is in extremely minute grains dispersed through the gangue so as to render it impossible to separate the stony parts by washing. The ore therefore after being picked by hand is pounded dry in a stamping mill and is thus reduced to the consistence of a coarse sand; in this state it is assayed, and contains on an average about $\frac{1}{133}$ of its weight of silver. As it holds no superfluous quantity of sulphur there is no necessity for roasting it previous to fusion. On account of the refractoriness of the ore, it is expedient to make use of quicklime, scoriæ from a preceding fusion, and slag from the iron forges by way of flux; and in order to furnish the proper quantity of lead of which the ore is naturally entirely destitute, it is mingled with pulverized galena, with the litharge and scoriæ furnished by the refinery, and with old cupels ground to powder, in such proportions that the lead obtained by the fusion shall contain 2 per cent. of silver, allowing at least 20 per cent. of the lead to be lost by evaporation or combining with the scoriæ. The above materials being properly mixed together are put into a powerful blast furnace, with alternate charges of charcoal, and the products of the fusion are lead holding silver, a black compact sulphureous semi-metallic substance called *Matt*, and scoriæ. The scoriæ undergo no further treatment, except that a certain portion is reserved as a flux for the next parcel of ore; the matt being tolerably rich in silver is remelted with litharge, and the lead obtained carries with it nearly the whole of the silver, so that it is not worth while to fuse again this second matt, although it still contains a portion of precious metal. The lead procured by these operations when refined yields about 2 per cent. of silver; the cupellation is performed at a higher heat than usual, which perhaps is rendered necessary by the presence of a little iron, the consequence of which is, that the loss of metal by evaporation, instead of being about 7 or 8 per cent. amounts at least to 20 per cent. and as every pound avoirdupois of the lead thus volatilized contains from 6 to 10 grs. of silver, the loss in this process is prodigious, and might in all probability be greatly diminished by the mixture of a much larger proportion of lead with the silver ore.

3. Other silver ores besides this metal afford both lead and copper; and as the treatment in this case is the most complicated, we shall give a short sketch of it. The process begins by

* Journ. des Mines, No. 59, p. 1.

mixing together some of the poorer kinds of meagre silver ore (that is, such as contains but little copper and lead, and much hard stony gangue) with the poorest pyritical ores (that is such as contain very little silver and copper but much sulphur and iron). To this is added by way of flux, a parcel of scoriæ remaining from a former process, and containing oxyds of lead and copper with a small portion of silver. All these materials being strongly heated in a blast furnace re-act on each other and enter into fusion; the stony gangue is dissolved and the fluid mass separates into two distinct parts. The heaviest portion, and which therefore occupies the bottom of the furnace, is called *matt;* it forms about ¼ of the whole mass, and contains all the silver, by far the greater part of the copper, a considerable part of the lead, together with iron, sulphur, and generally zinc and arsenic. The lighter portion and which swims on the surface of the matt is a black slag consisting for the most part of sulphur, oxyd of iron, and earth, the lead and copper being in such small quantity as not to be worth the trouble of extraction; this slag therefore is thrown away.

The crude matt obtained by the preceding operation is roasted to free it in part from the sulphur and other volatile impurities, and, being mixed with about 1½ times its weight of a richer sort of meagre silver ore, and about twice its weight of lead scoriæ by way of flux, is again fused, and furnishes a rich matt (containing from 9 to 10 lbs. of lead, 3 to 4 lbs. of copper, and 6 to 7 oz. of silver in the quintal) and a parcel of scoriæ that still hold a little silver, and are therefore employed as flux in subsequent fusions.

This second or rich matt, after being roasted, is mixed with about half its weight of litharge and scoriæ in equal proportions, and again fused; the product of which is, 1. a quantity of metallic lead holding from 6 to 8 oz. of silver in the quintal: 2. nearly an equal amount of copper matt, holding from 30 to 40 lbs. of copper, and about 4 oz. of silver in the quintal; 3. Scoriæ, holding from 6 to 10 lbs. of lead, and about 40 grs. of silver in the quintal.

The copper matt of the preceding operation after being roasted is fused together with a quantity of lead and copper scoriæ, and yields black copper, containing from 60 to 80 lbs. of copper, and from 5 to 10 oz. of silver in the quintal.

The black copper is now melted with litharge and scoriæ, by which the silver is for the most part transferred to the lead, and the copper after one or two more fusions is entirely freed both from lead and silver, as well as from sulphur, iron, and other impurities.

The rationale of all these processes is sufficiently plain. The silver, copper, and lead being all much more easily reducible than iron, are brought by means of the superfluous sulphur of the pyrites to the state of sulphuret, while the sulphurized oxyd of iron brings the earthy matters into fusion, forming a slag that is incapable of combining with the metallic sulphurets, and through which they fall in drops on account of their superior specific gravity. By the processes of roasting, the sulphur, arsenic, zinc, &c. are driven off, and the iron being oxydated quits the other metals, and unites with the scoriæ in the subsequent fusions; while the lead, silver, and copper of the scoriæ, pass through the vitrefied mass, and unite with the matt. The separation of the silver from the copper is effected by the superior affinity of the former with lead, assisted by the attraction subsisting between the copper and sulphur, which disposes this latter metal to yield the silver to the lead more easily than if the copper was pure.

Of Eliquation.

Silver is sometimes separated from copper by *Liquation* or *Eliquation.* This is an old process which appears to have fallen considerably into disuse, but it requires some notice in this place. When *copper matt* (or the black unrefined copper) contains silver in the proper proportion for this operation, it is first melted with lead or litharge, or a mixture of the two, and a reguline alloy is produced containing the copper, lead, and silver, which is cast into moulds so as to form round masses or loaves. These are then set in a furnace on an inclined plane of iron with a small channel grooved out, and heated to a very moderate redness, during which the lead melts or as it were sweats out of the loaf, and runs down the channel, conveying with it the silver, and the copper is left behind as a reddish-black spongy mass. The silver-holding lead is then worked off on a cupel in the usual way, and the silver is obtained separate.

This process is founded on the very weak affinity which lead has for copper, and the very strong affinity which it bears to silver, so that at a moderate heat the separation of the lead and silver from the copper is effected easily, but many circumstances must be attended to in order to perform this process with success.

The first consideration is the relative propor-

ons of the three metals. The lead is proportioned partly to the copper and partly to the silver. It should not be more than four times the weight of the copper, otherwise it will render the whole mass so fusible that instead of the lead and silver alone melting out, much of the copper will also mix with it, or if the heat be at all too much raised, the whole *loaf of liquation* will melt down, and the process must be begun again. On the other hand the lead should not be less than $2\frac{1}{2}$ times the copper, otherwise a great part of it, (and along with it part of the silver) will remain in the loaf after heating.[i]

The above therefore are nearly the extreme limits of the relative quantities of the lead and copper, and the exact proportion of lead is determined by that of the silver contained in the copper, which must be previously found by a small assay.

It is found that copper which contains more than about three quarters of a pound of silver in 100 lbs. will not yield all its silver by a single process of eliquation, which is doubtless because it will not bear alloying with sufficient lead to extract the whole, for in these circumstances, according to Cramer, every half ounce of silver requires 17 lbs. (or 544 times its weight) of lead for its extraction, allowing four times as much lead as copper. Hence the respective proportions of the three metals in a loaf of liquation would be 544 parts of lead, 136 of copper, and 1 of silver. These are nearly those that are actually employed, except that a less proportion of lead is found sufficient, being to the copper only as 11 to 3 instead of 12 to 3.

The whole process of obtaining pure silver by liquation is managed in the following way according to the accurate account given by Duhamel.[k] It consists essentially of five different operations. The first is the melting together the lead with the silver-holding impure copper in due proportions, and casting the mixed alloy into the proper moulds to form the loaves of liquation. The second process is the *liquation*, properly speaking, or the melting out from these loaves by a regulated heat, the lead and silver, and leaving the copper. The third is a second roasting of the porous loaves in order to melt out a portion of lead and silver, and other matters which remain after the foregoing operation. The fourth is the working off the lead on a large cupel or test to convert it into litharge, and leave the silver; and the fifth is the further purification of the silver by a second refining with lead. These two last processes have already been described when treating of the other methods of refining silver. There are besides other operations performed on the copper to refine it, and on the scoriæ to obtain all the metal that may adhere to them, but we shall here only describe the three first processes.

The fusion of the metals is performed in a high blast furnace, the bottom of which is lined by a mixture of charcoal rammed hard and laid in an inclined direction so as to convey the metal when melted into a separate receptacle adjoining. The crude black copper is previously broken into small pieces when hot, and assayed for the proportion of silver. Either lead or litharge is used in the mixture, if the latter, it is mixed with charcoal to promote its reduction. The furnace being previously heated for eight or nine hours and filled with charcoal, a basket-full of the scoriæ arising from the first reduction of the copper ore is thrown in, which soon melts and lines the furnace with a vitrescent glazing that protects its walls from the violent action of the blast. Soon after, about 20 lbs. of lead are thrown on the hot coals, and with it about half the copper intended for one loaf of liquation: 30 lbs. of litharge are thrown upon this, and with it a small basket of charcoal to reduce it. The rest of the copper and litharge are then added, and lead over the whole. The heat excited by the blast soon melts together these ingredients, reducing the litharge, and the whole falls down into the small well intended for the melted metal. When enough is collected for a single loaf it is tapped, and the metal is poured into an iron mould previously heated, and lined with a thin coating of clay. To withdraw the loaf from the mould, a strong iron bar bent at top is let into the hot metal about two inches, and when cold serves as a handle to draw up the loaf, and is knocked away when the loaf is taken out.

The heat required in this operation is less than that at which copper melts, so that the reduction of the litharge and mixture of the metals goes on very speedily. In a well managed furnace, seven loaves, each of about 350lbs., are cast in an hour. Litharge is not absolutely necessary, but on the whole is preferable to using lead alone as it is a powerful flux before reduction, and there is always a great quantity of it produced in the subsequent refining of the lead and silver. In estimating the proportion of the metals, 120 lbs. of litharge are taken as equivalent to 100 lbs. of lead.

[i] Crameri Docimasia practica: processus 48.

[k] L'Art de Liquation, Mem. de l'Acad. for 1788.

These proportions are nearly those that have been given above. In Germany, where the works are carried on on a large scale, the loaves are usually about 350 lbs. in weight, and are composed, when the copper is rich in silver, of 3 parts of black copper, (75 lbs.) and 11 parts of lead, (275 lbs). In this case where the silver is ¾ per cent. of the copper, the relative proportions of these metals will be about 1 part of silver, 132 of copper, and 488 of lead. Where the copper is poorer, only 10 parts of lead are used to 3 of the copper.

The next process is the *Liquation*, and is performed in a furnace constructed for the purpose, which generally holds six loaves, set on iron bars, separated from each other by bricks, and having a channel beneath to convey the lead and silver into a separate bason. The management of the heat in this process is of the greatest consequence. If it goes on properly, the lead flows out easily, and the loaves gradually sink down and become honey-combed, but without losing any sensible portion of the copper. If the heat is too great, particles of the copper are seen to flow away along with the lead, on which the fire must be immediately damped. When no more lead flows out at this temperature, the loaves are taken out, and when cold they have a dark red colour, and are very crumbly. It takes about four hours to eliquate the six loaves.

Whatever care is taken in this process there always remains a little silver in the loaves, which however, does not amount to more than about half an ounce in 100 lbs. when well performed. Some of the lead also remains, together with part of the iron, arsenic, sulphur, and other impurities of the copper. The first portion of the lead that flows out of the loaves is the richest in silver, that which remains in the loaves is very poor, but still is worth extracting, and is performed in the following way. When a sufficient number of the loaves remaining after liquation are collected they are ranged in a kind of oven so as entirely to fill it, which takes about 150 pieces; they are then heated by the flame of charcoal and green wood, drawing through the oven till they are moderately red-hot, at which time a quantity of metal and scoriæ sweat out and drop down in the hearth, consisting of a heterogeneous mass of lead holding a little silver, of scoriæ, of litharge, arsenic, oxyd of iron and sulphur, and also of some copper if the heat is raised too high. This mass is washed with water, by which the scoriæ are got rid of, the silver-holding lead alone remains. When the droppings from the furnace begin to be red and compact, it is a sign that all the heterogeneous matter is extracted, and that the copper itself begins to melt, on which the fire is removed. The loaves are then taken out, and appear varnished over with a thick vitrescent scoria, which, on dropping them into water, cracks in every direction, and is then readily knocked off by hammers, and the copper within is found considerably pure. This process lasts about 30 hours, half of which time is consumed in bringing the loaves to the proper heat.

The subsequent processes of refining the silver-holding lead on a test have been already described.

The process of eliquation, though highly ingenious, is considerably expensive and troublesome, and it appears to require no small degree of skill to conduct it properly. To be performed economically it is also necessary that the copper should hold a particular portion of silver, (neither more nor less within certain limits) that is from ⅔ to ¾ per cent. of silver, and hence, where there are quantities of copper of different richness in silver, much judgment may be shewn in mixing them so as to produce a metal which may be eliquated with most profit. But where there are natural or artificial alloys of silver and copper much richer in silver than those above mentioned, the process of eliquation must be repeated two or three times on the same metal, which would be extremely expensive and troublesome.

Reduction by Amalgamation.

This most ingenious method of working silver ores, was first practised by the Spaniards in South America, and has since been adopted with numerous and essential improvements, in Saxony, Bohemia, Hungary, and some other parts of Europe. We shall proceed to describe the most approved modern method of performing this operation.

Those ores alone are amalgamated that come under the description of hard or meagre; that is, which contain none, or at least only an inconsiderable quantity, of lead or copper. It is of importance however, that they should contain a certain proportion of iron pyrites, and if a sufficiency of this is not naturally mingled with the ore, it is a very judicious practice to add it to the dressed ore, so that its pyritical contents shall always be brought to bear a certain proportion, as nearly as possible, to the silver, the amount of which latter must be determined by a previous assay.

The ore, if washed, is of a sufficient degree of fineness, without having recourse to grinding, but it only hand dressed, it must subsequently be reduced in a mill to the consistence of coarse sand. This being done, common salt must be accurately mixed with the ore in the proportion of 8 or 9 *per cent.* if the silver in the ore amounts to 8 oz. per quintal, and from 10 to 12 *per cent.* if the silver amounts to 32 oz. or even more. The next process is roasting: for this purpose about 3 quintals are spread on the floor of a reverberatory furnace, and exposed to a moderate red heat for four or five hours, till the emission of vapours has almost entirely ceased, care being taken to turn it over two or three times during the roasting, that every portion may be in its turn exposed to the action of the fire. When this first change is withdrawn, an experienced workman can tell by its appearance whether the proportion of salt has been too much or too little, and the necessary correction is accordingly made by adding more salt or ore to the unroasted parcel. The whole of the ore being properly roasted, is ground in a mill, and afterwards passed through sieves, by which it is rendered as fine as meal, and is then fit for the process of amalgamation, properly speaking.

This is performed in an apparatus consisting either of a number of small barrels made to revolve rapidly on their axes by mill-work; or of a number of fixed tubs, open or covered, with an instrument resembling a chocolate mill placed in the centre of each, and capable of being turned rapidly by the same kind of machinery as puts the barrels in motion. These tubs or barrels are filled about one-third with water, and then a sufficient quantity of roasted ore and mercury, in nearly equal proportions, is added, to bring the whole to the consistence of thin mud. The machinery is now put in motion, and is continued incessantly for from thirty to forty-eight hours, according to the richness of the ore, at which period the amalgamation is compleated. In about a quarter of an hour after the mill is stopped the greater part of the amalgam will have descended to the bottom of the vessels, and is accordingly withdrawn, by unstopping a hole made for that purpose.

The earthy residue is then carefully washed by small parcels at a time, and thus much amalgam, which from its minute state of division was unable to sink through and mix with the rest, is recovered. But the earth, especially if it was at first rich in silver, still retains a portion of precious metal: it is accordingly dried, mixed with about 3 *per cent.* of salt, again roasted, and at a higher heat than at first, and again amalgamated, by which the whole of the silver is extracted.

The amalgam, which is very fluid, is strained through a closely-woven bag, by which it is separated into nearly pure mercury, and a stiff amalgam: this latter is then subjected to distillation *per descensum*, in an apparatus that cannot be described without the assistance of plates of reference, and is thus separated into silver and mercury. The silver however still contains a little copper, from which it is freed by cupellation in the usual way.

The theory of the process of amalgamation appears to be this. By the roasting, the sulphur of the silver and pyrites is for the most part burnt off and converted into sulphureous acid, which acid as soon as formed, assisted also by the affinity of the silver for muriatic acid, decomposes the common salt, and forms with its base either sulphat or sulphite of soda, while the muriatic acid combines with the silver, forming luna cornea. In the subsequent amalgamation, the mercury being present in great abundance decomposes the muriat of silver, and is itself partly converted into calomel, while the rest of the mercury combines with the reduced silver into an amalgam. Hence the loss of mercury which always happens in this process depends on two causes, first, the conversion of a part of it into calomel (and this cannot by any care in manipulation be avoided) and, secondly, the division of a part into such minute globules, as enables it to pass off unperceived in washing the earthy residue: the proportion of this however depends greatly on the care and dexterity of the manipulation.

We shall close this section by mentioning in a few words a method invented by Napione,[1] of separating silver from copper, without having recourse to the more expensive and tedious method of eliquation. The mixed metal being melted, some sulphur is to be sprinkled over its surface, while an assistant stirs the whole about with a stick; the sulphur thus combines with the copper into a matt, which floats above the metal, and is to be removed with a pair of tongs, after having moistened its surface with a little water, in order to solidify it. A fresh portion of sulphur is then to be stirred in, and the matt thus produced is to be removed as before; by repeating this a sufficient number of times the greater part of the copper is converted into matt, holding a little silver, while

[1] Ann. de Chim. xli. p. 160.

the residual copper, by retaining most of the silver that was at first diffused through the whole mass, becomes rich enough to be passed immediately to the refinery. The matt is to be ground to powder, and mixed with common salt and quicklime, in the proportion of 12 *per cent.* of each, and is then to be roasted for 10 hours. This being finished, it is to be amalgamated in the manner above described, and by three successive roastings and amalgamations the whole of the silver may be extracted.

§. 4. *Physical and Chemical Properties.*

SILVER is a metal of a beautiful white colour, perfectly free from taste and smell. The colour is very distinguishable from that of every other metal, being a pure brilliant white, free from any other admixture of hue. Its specific gravity when simply fused in mass is about 10.4 which is somewhat increased by hammering or lamination, but less so than most other metals. It is a soft metal, being easily scratched by copper. It is considerably elastic, and when hardened by alloying, is highly sonorous, and even in small quantity much increases the sonorousness of the *Alloys of* COPPER, as mentioned under that article. Silver is one of the most extensible metals that we are acquainted with, its ductility is only less than that of gold, in consequence of which it may be beaten out into extremely fine leaves, and drawn out into wire thinner than the finest human hair. For this latter purpose however a small alloy of copper is found necessary, though less than that of standard silver, which is one twelfth. Hence the silver procured from the silver and silver-gilt wire used for laces, embroidery, and other ornamental purposes, bears a higher price than any other usually met with. This metal is also very tenacious, so that a wire a tenth of an inch diameter will support about 240 lbs. without breaking.

Silver, when quite free from alloy, melts in a moderately intense red-white heat, so that a plate about the dimensions of the thinnest pasteboard, will scarcely support the fullest heat of a very brisk fire in a common grate. When in fusion, if pure, the surface is most strikingly brilliant and beautiful, and like a white polished mirror, but as it congeals, it becomes of a clean dead white. If cooled hastily, the surface as it fixes shoots up into small irregular projections with some little force, so as to disperse a few particles of that part of the metal still in fusion. Hence in the delicate business of the *assay* arises the precaution of cooling melted silver very gradually while it is fixing. Pure silver is not sensibly volatilized by being kept in a heat not much above its melting point for any length of time, though when mixed with another metal which is itself volatile, either in the metallic or oxidated state, a little of the silver is then dissipated. Silver is a *perfect* metal, that is, it does not oxidate by being kept in fusion whilst exposed to air. This position however, though sufficiently accurate for all practical purposes, requires some limitation; for when this metal is intensely heated with access of air, the support on which it stands gradually becomes yellow, owing to the formation of an oxyd of silver.

The same change takes place, as was observed by Darcet, Macquer, and others, on inclosing silver within small porcelain balls, and exposing them to a very long continued and intense heat, after which a loss of silver is experienced, and the earthen vessels are found enamelled with a yellowish-white vitreous glazing, resulting from the union of the vitrified oxyd with the earth of the porcelain, through whose pores sufficient oxygen had entered to oxidate part of the silver. The pure oxyds of silver are however reducible to metallic silver by mere heat, when not in contact with any earth or other substance with which they can vitrefy, so that the permanence of the oxyd in this instance is owing to its intimate union with the earth. Under the blow-pipe, silver, when intensely heated, emits copious fumes, which will render brown a surface of gold exposed to it, and consist of the silver volatilized by the extreme heat. The pure oxyd cannot be prepared by mere heat, but is readily furnished by the precipitation of the acid solutions by an alkali. In this state it is insoluble in water, free from taste, and cannot be sublimed, but when heated *per se* it returns to its metallic state, except the part immediately in contact with any earthy matter which becomes fixed by vitrefying with it.

Silver is nearly unalterable by simple exposure to air and moisture, so that it is incapable of rusting. A polished surface of this metal will remain bright for some time in a pure air free from sulphureous and animal vapours; by degrees however the metal becomes dull and brownish, and after a while a very slight coating forms on its surface, which rubbing with any soft powder will take off, and the brightness will be restored with scarcely any loss of weight, the outer coating long protecting the metal within from further change. This takes place,

however, much more rapidly when the ſilver is alloyed (as in the common plate) than when pure. In general the *tarniſh* of ſilver is in too ſmall a quantity to be examined, but when this metal has been expoſed for a very long ſeries of years to the common air of towns and inhabited places, the corroſion penetrates deeper, and the altered part will readily peel off. This however is not the pure oxyd, but the ſulphuret, as was aſcertained by Prouſt, the properties of which will be afterwards deſcribed, ſo that we know of no ſimple oxyd of ſilver formed ſpontaneouſly in the air.

Water has no effect whatever on ſilver at any temperature, and is not decompoſed upon it. But when bright clean ſilver is immerſed in common natural waters, particularly thoſe that receive the refuſe of animal or vegetable matter, in no great length of time the whole becomes tarniſhed and brittle, and is converted into a ſulphuret.[m]

Though ſilver at no temperature undergoes combuſtion by ſimple contact of common air, or oxygen gas, yet it burns totally and moſt beautifully in the electric and eſpecially the galvanic circles. Silver wire or leaf applied to a powerful galvanic apparatus, burns moſt readily with an exquiſite green flame, and a denſe grey ſmoke.

The ſulphuric acid has no effect on ſilver in the cold in any ſtate of dilution, but when the acid is concentrated and a boiling heat is employed, effervеſcence begins, an abundance of very pure ſulphureous acid gas is given out (as with this acid and mercury) and the metal is changed to a white pulverulent maſs, or is diſſolved entirely into a denſe clear liquid if the quantity of the acid is about four times that of the ſilver, which latter ſhould be added in ſmall ſhreds or grains.

This ſolution is extremely ſtyptic and requires an exceſs of acid. By evaporation it furniſhes ſmall white brilliant needled cryſtals.[a]

Sulphat of ſilver when heated *per ſe*, melts and ſwells up, and is not changed in a moderate heat, but, on increaſing it, blackens,[b] exhales ſulphureous acid and oxygen, and finally returns to the pure metallic ſtate. This ſalt is ſlowly diſcoloured by light, and turns of a blackiſh brown. None of the acids except the muriatic alter it, but this, in whatever combination it be, ſeizes upon the whole of the ſilver and unites with it into that curdy ſubſtance, the muriat of ſilver or luna cornea, which will be preſently deſcribed.

With alkalies and other decompoſing ſubſtances the ſulphat of ſilver is decompoſed nearly as the nitrat. Sulphat of ſilver is alſo formed by adding to nitrat of ſilver either ſulphuric acid or any alkaline or earthy ſulphat. The reſult in either of theſe caſes is a white heavy precipitate of ſulphat of ſilver which is inſoluble in water, but with a freſh portion of ſulphuric acid forms a ſolution ſimilar to that already deſcribed.

The precipitated oxyd of ſilver diſſolves more eaſily in ſulphuric acid than the metal.

The ſulphureous acid has no action on ſilver but readily combines with its oxyd. This ſolution cryſtallizes ſpontaneouſly in ſmall pearl-grey brilliant grains, unaltered by light.[c] The ſame ſalt is procured (as in the former caſe) by adding to the nitrat of ſilver either ſulphureous acid or a ſulphite of potaſh or ſoda. The ſulphite of ammonia diſſolves the oxyd of ſilver, which it detaches from its combination with the nitric acid and (agreeably to the uſual habitudes of the ammoniacal ſalts) produces a triple ammoniaco-ſulphite of ſilver, which by expoſure to the air becomes converted into a ſulphat.

The nitric acid diſſolves ſilver eaſily, and in large quantity, and is the acid conſtantly employed for this purpoſe in the arts. The concentrated acid ſhould be diluted with from two to four parts of water. Very ſoon after the ſilver is immerſed in the acid a ſtrong effervеſcence begins, much nitrous gas is given out, which forms a copious orange-coloured vapour as it eſcapes from the veſſel, and the acid aſſumes a light blue-green colour which is independant of any copper which the ſilver may contain, and is owing to the ſolution of a portion of the nitrous gas in the acid. If however the ſilver contains copper this increaſes the blueneſs, and the colour remains after the ſolution is cold and ſaturated, which is not the caſe when the ſilver is pure. A conſiderable heat is excited by the action of the acid on the ſilver, which alſo much aſſiſts in the rapidity of the proceſs, ſo that where the quantity of each is at all conſiderable no artificial heat is required. The ſolution is made very conveniently by putting the ſilver (granulated or in ſhreds) into a decanter or matraſs, adding the acid, and to it about four parts or more of *hot* water, and ſetting it under a chimney to draw off the fumes. The ſolution then begins almoſt immediately, and goes on with increaſing violence for a time and then continues ſteadily till the ſilver is diſſolved or the acid ſaturated,

[a] See Wiſeman and Hatchett in Phil. Trans. vol. lxxxviii. [b] Beaumé. [c] Fourcroy.

without requiring any artificial heat. Towards the end however it may be boiled for a few minutes where perfect ſaturation is wanted, or where every atom of ſilver is to be ſeparated from gold as in the proceſs of parting deſcribed under the article *Aſſay*. If the effervеſcence is too violent, ſo as to endanger an overflow of the contents of the veſſel, it muſt be moderated by adding cold diſtilled water.

When the ſilver contains a little gold as is the caſe with a large proportion of the ſtandard ſilver in uſe, the gold is left behind after the ſolution of the ſilver in the form of a black powder, which when collected, and fuſed with a little borax, appears in its reguline ſtate.

When the nitric acid contains either muriatic or ſulphuric acid a milkineſs is perceived as ſoon as the effervеſcence begins, owing to the ſeparation of the firſt portions of the diſſolved ſilver from the nitric acid in the form of an inſoluble ſulphat or muriat. Where the quantity of theſe foreign acids is but ſmall, it does not materially impede the proceſs, and theſe inſoluble ſalts, after the nitric acid is fully ſaturated, fall to the bottom by ſtanding at reſt for ſome hours.

A ſmall quantity of the nitrat of ſilver is volatilized along with the nitrous gas during the ſolution, eſpecially if carried on with rapidity, and at a conſiderable heat.[p] This is proved by condenſing the vapour in a receiver, containing a clear ſolution of common ſalt, which is thereby rendered milky.

Liquid nitrat of ſilver is perfectly clear and colourleſs in caſe the ſilver was pure, but if ſtandard ſilver be employed the colour is a light blue, owing to the preſence of copper. When at all concentrated its taſte is exceſſively ſtyptic and bitter, and it rapidly corrodes the ſkin of the tongue. Even in extreme dilution the bitter ſtyptic metallic taſte, is very ſenſible, and it remains for a long time in the palate. This ſalt blackens every part of the ſkin and all other animal matters. The blackneſs however does not come on till after the part has been expoſed for ſome time to the light, and is therefore particularly haſtened by ſunſhine; but the mutual action between the ſalt and the ſkin, is ſo ſudden, when the ſolution is concentrated, that a few ſeconds of contact will be ſufficient infallibly to produce the effect though it be carefully waſhed off immediately after. This ſtain laſts for ſeveral days, and only goes off by the natural change of the cuticle, ſo that in dead animal matter it is indelible.

The blackneſs is owing to a reduction of the metal in exceſſively minute particles; for when examined in a ſtrong ſun-ſhine with a powerful microſcope the particles of metallic ſilver may be diſtinguiſhed.

Moſt vegetable ſubſtances are alſo ſtained by this ſalt, though in a leſs degree, and leſs permanently.

When this ſolution is ſufficiently concentrated it readily cryſtallizes on cooling. The form of theſe cryſtals is generally ſix-ſided, or ſquare thin plates, often ranged like the ſticks of a fan, and forming very beautiful groups. This ſalt is not deliqueſcent, and is ſoluble in about four parts of cold water and much leſs of boiling.

It appears to contain but little water of cryſtallization, for when moderately heated it melts, and may be kept at that ſtate without loſing more than one per cent. of its weight. By cooling it then concretes into a dark grey maſs, which is the nitrat ſcarcely altered, and when rediſſolved in water will again cryſtallize. This grey ſolid nitrat forms a very valuable cauſtic for the uſe of ſurgeons, and for convenience is caſt in oiled moulds into pieces about the ſize of pencils, which are called *lunar cauſtic* or *lapis infernalis*. This is actually prepared however without the trouble of cryſtallization, ſimply by evaporating the nitrat of ſilver to the proper degree, and cooling the reſidue in the proper moulds. When one of theſe pencils is broken acroſs it preſents a radiated texture. The degree of cauſticity of this ſubſtance is by no means ſo powerful as that of the ſolid alkalies, for it corrodes the cuticle with difficulty, and it requires ſome hours to deſtroy the ſurface of the fleſh.

There are two great agents which moſt powerfully decompoſe nitrat of ſilver, light and heat. Light has no action on the liquid ſolution when kept in a bottle, full and well ſtopped, but if any portion is ſpilt, and the moiſture evaporates, the remaining nitrat blackens, is decompoſed, and when diffuſed in water it is no longer entirely ſoluble, but a black powder ſubſides, which is ſilver nearly if not wholly in the reguline ſtate, and minutely divided.

Heat alſo totally decompoſes this ſalt, for if it is heated at all beyond the ſtate of lunar cauſtic, globules of reduced ſilver are found

[p] Prouſt J. Phyſ tom. 62, p. 212, &c.

diffuſed in the maſs. By making the experiment in a glaſs retort, and a proper apparatus, the ſalt will be found to give out nitrous gas, oxygen, a little azot, and at laſt nothing remains but the ſilver, very pure, white, and ductile. If a piece of this ſalt be laid on red hot charcoal it deflagrates like common nitre, and when this is over, the charcoal is covered with a ſtrongly adhering coat of ſilver, which by a little rubbing appears of its natural colour.

The compoſition of nitrat of ſilver is given by Prouſt, as follows: 100 parts of the fuſed nitrat decompoſed by heat leave 64 of pure ſilver, whence 100 parts of ſilver would form 140 of the nitrat. On the other hand 100 parts of ſilver unite with 9.5 of oxygen when oxydated in the degree in which the metal exiſts in the nitrat, whence 100 parts of the nitrat would be compoſed of about,

Silver	64	70
Oxygen	6	
Nitric acid	-	30
		100

The actual quantity of lapis infernalis uſually obtained from ſilver is about 13 drachms from 8 drachms of pure ſilver, but only 10 or 11 drachms from the ſame quantity of ſtandard ſilver.[q]

Nitrat of ſilver detonates moſt violently with phoſphorus. If a ſmall cryſtal of nitrat of ſilver is laid on an iron anvil, and about half a grain of phoſphorus is put upon it and ſtruck ſmartly with a hammer it explodes with a very violent report. A greater quantity of theſe materials might be dangerous to the operator. The iron is found after the exploſion covered with minute particles of metallic ſilver.

Phoſphorus will alſo reduce the nitrat of ſilver in the moiſt way. Put a ſtick of newly melted phoſphorus into a very dilute ſolution of nitrat of ſilver, and in half a day it will be ſilvered on its ſurface, and gradually the whole of the ſilver precipitates on the phoſphorus in fine dendritic cryſtals.

Hydrogen alſo rapidly reduces the nitrat of ſilver, and during its reduction it paſſes through various ſhades of brown, till it acquires the metallic luſtre. A coating of ſilver may be thus fixed on ſilk, as Mrs. Fulhame has obſerved in her ingenious experiments,[r] by moiſtening the ſilk and expoſing it while wet to a current of hydrogen gas. Thus placed, the ſilk becomes gradually brown, and as the reduction advances the ſurface is covered with an irideſcent pellicle of various colours whilſt a firm coating of ſilver fixes to the threads. It was found impracticable however to produce an uniform perfect ſilvering by this method, for though many particles of bright white metal may be obſerved, the general appearance is tarniſhed and void of luſtre.

Nitrat of ſilver is alſo reduced very readily upon charcoal by the ſun's rays, or by expoſure to a heat of boiling water without the aſſiſtance of light. This reduction forms ſome beautiful experiments, which are given by Count Rumford.[s] Some charcoal was firſt boiled for ſome time in diſtilled water, till it had become ſo much wetted as to ſink in this fluid. A piece of it was then introduced into a phial containing a moderately dilute ſolution of nitrat of ſilver in diſtilled water (this ſalt having been previouſly fuſed and reduced to the ſtate of lapis infernalis to drive off what little exceſs of acid the cryſtallized ſalt might contain) and it was ſet in a ſtrong ſun-ſhine. In leſs than an hour ſmall ſpecks of revived ſilver appeared on the charcoal, and this depoſition of ſilver continued till the charcoal was covered with ſpangles of reduced ſilver perfectly white and reſplendent. The ſame experiment was repeated with the difference that the phial was incloſed in a tin box and expoſed for an hour to the heat of boiling water in a common ſteamer uſed for boiling potatoes. When examined, the ſurface of the charcoal was covered with a moſt beautiful metallic vegetation, ſmall filaments of revived ſilver reſembling fine flatted wire puſhing out from the ſurface in all directions, and extending to the diſtance of a tenth of an inch.

Silver is precipitated from its nitric ſolution by mercury. If the ſolution contains both ſilver and mercury, and the precipitating metal be alſo a compound of mercury and ſilver, a curious and beautiful precipitation of a brilliant alloy of theſe two metals is depoſited in an arboreſcent form which has been called the *Arbor Dianæ* or *Silver Tree*. Lemery was the firſt who obſerved this curious metallic vegetation, and various proportions of the ingredients have been given by different chemiſts, all of which ſucceed to a certain degree. The moſt eſſential point ſeems to be, that in the ſolution the ſilver ſhould much exceed the mercury, but in the precipitant the mercury ſhould exceed the ſilver. The proportions given by

[q] Beaumé. [r] Eſſay on Combuſtion. [s] Phil. Tranſ. vol. 88, p. 460.

Baumé are the following: Make an amalgam of one part of leaf silver with seven of mercury, which will unite by simple triture into a mass of the consistence of soft butter. Put a small lump of this amalgam about the size of a bean, into a bottle containing a mixture of six drachms of a saturated nitrat of silver with four drachms of a similar solution of mercury, diluted with five ounces of water. Set the bottle in a place where it may remain perfectly at rest, and the expected metallic vegetation will generally succeed. It begins by the appearance of small spiculæ sticking on the surface of the lump of amalgam, which after a while increase to broad brilliant blades elegantly arborescent, which, if the bottle is kept at rest, have consistence enough to keep together, and imitate a shrub in form.

The time required for this depends on the degree in which the solution is diluted; in general, with the above proportions the first filaments form in a few minutes, but it takes a day or two to compleat the precipitation. This precipitate is brittle, harsh to the touch, and very brilliant. The amalgam on which it is based loses much of its metallic lustre and becomes much harder than at first, and brittle, instead of being of the consistence of butter. Mercury alone will answer the same purpose as the amalgam, but the silver tree is more brittle and sooner falls down by its own weight.

Nitrat of silver is decomposed by the fixed alkalies pure or carbonated, and by the alkaline earths. With the pure alkalies and earths a grey precipitate is formed, with the carbonated alkalies a yellowish white. In the former case, 100 grs. of the precipitate are produced (according to Bergman and Wenzel) by about 89 of silver, and in the latter by about 77.

Ammonia first gives a precipitate which it speedily redissolves, and forms with some particulars in the management the fulminating silver, which will be presently described. Carbonat of ammonia gives a white or a dark precipitate, according as it is more or less saturated with carbonic acid. All these oxyds turn blackish by exposure to light.

Many other metals also separate silver from its solutions in this and other acids, and particularly copper, which is employed largely for this purpose by the refiners. In assaying gold (as mentioned under the article *Assay*) the cupelled button of gold and silver is treated by nitric acid to dissolve out the silver and leave the gold pure. After this process (which is called *parting by aqua-fortis*) a nitrat of silver is left, which when a sufficient quantity is collected is thrown into a copper bason sometimes also with pieces of copper immersed, and the silver is reduced in its perfect metallic state in the form of thin brittle leaves, and the bason now contains nitrat of copper. The latter again decomposed by lime yields the pigment *Verditer*. The whole of the silver is not however separated by copper, for the solution becomes milky on adding common salt. The reduced silver also contains a small quantity of copper. Still it is a very useful and convenient way of recovering the silver immediately in the metallic state, and is employed both in the large way and in analysis.

Nitrated silver is also decomposed by a great variety of alkaline and earthy salts, particularly by the sulphats, muriats, phosphats, &c. that is by all those whose acids united with silver produce an insoluble salt. Of these the muriat of silver is the most important, and will be presently mentioned.

Several of the metals are found to combine with the acids in two proportions, one, where the ingredients are in mutual saturation, or else where the acid is in excess, and the other where the metallic oxyd predominates. Prof. Proust[a] has given the following account of the nitrat of silver with excess of oxyd, or *sub nitrat*.

It is prepared by boiling a saturated solution of the common nitrat of silver with reguline silver in that state of fine flocculi in which it appears when precipitated by copper. Nitrous gas is given out during the ebullition, which is to be continued for about an hour, and the vessel then corked and set by that the undissolved portion may subside.

The solution is of a clear yellow colour, and is the sub-nitrat in question. Being much more soluble than the nitrat it may be concentrated to a much greater degree by evaporation in a retort or mattrass into which a few pieces of silver are to be put to preserve the excess of this metal. During the evaporation some of the salt is volatilized. It is very difficult to obtain this sub-nitrat in regular crystals, for, when sufficiently concentrated, the whole is very apt to congeal into a white shapeless mass, during which a sensible heat is given out.

This solution differs from the common nitrat in many particulars. Its colour is yellow, but the nitrat is without colour; the sub-nitrat

[a] J. Phys. tom. 62, p. 220.

changes the colour of litmus blue, and gives a blue lake with it, but the nitrat produces no effect: the nitrat turns cochineal ſcarlet; the ſub-nitrat, deep yellow: the nitrat does not change ſulphat of indigo; but the ſub-nitrat diſcolours it entirely, and the ſilver is reduced. Ammonia gives a black precipitate with the ſub-nitrat which is ſimply reguline ſilver in minute diviſion and does not fulminate; nor is the precipitate rediſſolved by an exceſs of ammonia, but the clear liquor contains oxyd of ſilver diſſolved in this alkali. When the ſolution of the ſub-nitrat is expoſed to the air, in a few days it loſes its yellow colour, and depoſits large blades of cryſtallized nitrat of ſilver. The cryſtals are then in the ſtate of common nitrat, ſo that the two ſalts differ both in the quantity of acid and of oxygen being leſs in the ſub-nitrat. If ſome drops of nitric acid are poured into the concentrated ſolution of the ſub-nitrat large cryſtals of nitrated ſilver form almoſt immediately, the yellow colour is loſt, and the whole becomes common nitrat. If the ſolution is leſs concentrated, and nitric acid is added, nitrous gas is given out.

If muriatic acid is added to the ſub-nitrat, common muriat of ſilver is precipitated, ſo that the ſupernatant liquor ought to be ſtill leſs oxygenated than before.

Water acts in a ſtriking manner on the ſolid ſub-nitrat. If *cold* water is poured on it a part only diſſolves, and the reſidue is a yellow powder, a compound of ſilver, nitric acid, and oxygen, in which the two latter ſubſtances are in ſtill ſmaller proportion to the metal than in the liquid ſub-nitrat, or the ſolid ſalt before the affuſion of water. The ſalt therefore divides itſelf into two portions, the ſoluble part abſtracting from the other a portion of its acid and its oxygen, which is nearly ſimilar to what takes place with the ſulphats of mercury during the formation of turbith, and with the nitrat of this metal. If *boiling* water is added to the ſolid ſub-nitrat, theſe changes proceed ſtill further and the inſoluble portion becomes ſucceſſively, but almoſt inſtantaneouſly, yellow, red, and black. If whilſt it is yellow or red, a few drops of nitric acid are poured in, the further change is ſtopped and the whole diſſolves into a colourleſs ſolution, but after the colour has become black, this does not take place. This black powder is merely ſilver in fine diviſion, and ſilvers the bottom of the veſſel by ſtanding.

If the ſolid ſub-nitrat is ſtill further heated in a retort, it thickens, gives out nitrous gas, fuſes, and a yellow ſublimate ariſes. No ſuch ſublimate is formed with the nitrat. The above facts ſhew that there are at leaſt two ſtates of oxydation of ſilver when in ſolution, but the ingenious diſcoverer does not give the proportions of the ſub-oxyd.

All the ſolutions of ſilver are blackened immediately by ſulphuretted hydrogen, either in the gaſſeous or liquid ſtates, and all the ſolid ſulphurets produce the ſame change on ſilver, as will be preſently mentioned.

A compound acid, extremely uſeful for diſſolving ſilver when mixed with copper and ſome other metals, has been diſcovered by Mr. Keir.[u] It is formed by diſſolving one part of nitre in about eight or ten parts by weight of ſtrong ſulphuric acid. When pieces of ſilver are thrown into this acid (undiluted with water) and a heat of from 100° to 200° is applied, an effervescence of nitrous gas takes place and the ſilver is diſſolved. This makes a very denſe heavy ſolution which readily concretes by cooling, but may be moderately diluted with water without becoming turbid. This compound acid (which may be termed the *nitro-ſulphuric*) diſſolves about a fifth or a ſixth of its weight of ſilver, and with much more eaſe than the ſulphuric acid ſingly would do. The quantity of nitrous gas given out in the proceſs ſeems to be leſs in proportion as that of the nitre is greater. The nitro-ſulphuric acid, undiluted, alſo oxydates and partly diſſolves tin and mercury, but it hardly touches copper, lead, gold, or iron. Hence it is particularly uſeful in recovering the ſilver from the ſurface of any ſilver plated metal, which is an object in large manufactures of plated goods, and was uſually done from copper plate at Birmingham by more expenſive methods. The preciſe proportions of ſulphuric acid and nitre are not of much conſequence. On the other hand if water is added to the acid, its power of diſſolving ſilver is much leſſened, and it then acts on copper with eaſe.

The ſilver may be recovered from the ſolution either by adding common ſalt which ſeparates it in the form of muriat of ſilver (which is afterwards reſtored to the metallic ſtate by fuſion with alkalies) or, more ſimply, by diluting the ſolution with water and continuing to immerſe the ſame pieces of copper plate which have loſt their ſilvering. The acid being now able to act on the copper will ſaturate itſelf with this metal in preference, and will depoſit the ſilver in the metallic form. The ſulphat

[u] Phil. Tranſ. vol. 80.

of copper may then be applied to several uses. The first way however gives a purer silver.

Sulphuric acid impregnated with nitrous gas (a combination first noticed by Dr. Priestley) dissolves silver with effervescence as soon as heat is applied, the solution becomes of a violet colour and much nitrous gas is disengaged. By moderate dilution a white saline powder falls down which is redissolved in more water. The undiluted solution saturated, and set in a cool place, readily congeals, but when diluted slightly it gives foliated crystals.

The carbonic acid has no action on silver or its oxyd, but a carbonated oxyd insoluble in water is formed by precipitating the nitrat or any other solution by a carbonated alkali. This substance is a yellowish white powder, which by exposure to light, soon turns blackish, and in time it contains a sensible portion of metallic silver. It is a convenient preparation for making the salts of silver with those acids, which, like the acetous, do not act on this metal in the reguline state.

Muriatic acid is usually said to have no action on reguline silver either hot or cold. This is the fact (generally speaking) for the action in a moderate time is so small that the silver hardly appears corroded, though after a certain time and particularly with the assistance of heat the metal is converted into an insoluble muriat and the remaining acid which is proportionally weakened retains scarcely a particle of the muriat in solution.[w] But the oxyd of silver readily unites with this acid and forms a white curd-like mass insoluble in water. This combination however is more frequently made by the mode of precipitation, and occurs whenever muriatic acid, or any alkaline or earthy muriat is added to any salt of silver except the prussiat. In this case if the solutions are at all concentrated, at the moment of mixture a white curd-like substance separates, and speedily sinks to the bottom, which is the *muriat of silver* or *luna cornea*. This precipitation is one of the most familiar to chemists, for being perfectly insoluble in water it shews itself when the most minute quantities of muriatic acid and silver are present, and thus it forms a most useful test for either substance.

When the quantity is extremely small indeed, no actual precipitate can be collected, but the solutions which were limpid before mixture become more or less opalescent afterwards. Thus the purest natural waters contain some particles of common salt or earthy muriats, and therefore if a drop of nitrated silver be shaken with a bottle full of water, it becomes almost immediately milky or opalescent according to the quantity contained. This test is so delicate that it will even detect the minute portion of muriat of soda adhering to the skin, for if a phial containing distilled water with a drop or two of nitrat of silver be shaken, with the thumb used as a stopper, in a short time it will have dissolved enough of salt from the surface of the cuticle to become slightly opalescent on standing.

Muriat of silver does not separate compleatly from the liquor of the solution in which it is formed, till all the silver is precipitated, for whilst any remains in solution, though the curdy precipitate is copious, the supernatant liquor also remains very milky, but as soon as sufficient muriatic acid is added to engage the whole of the silver, the liquor becomes limpid almost suddenly. The muriat may then be collected and edulcorated with the utmost ease, more so than any other known precipitate. It retains the last portions of water however, with considerable obstinacy, so that it cannot be thoroughly dried at the heat of boiling water, without remaining in that temperature for a considerable time. When perfectly dry it is in hard harsh-feeling lumps, which do not in the least soil the fingers.

Muriat of silver melts at a heat somewhat below redness, (that is about the degree at which lead melts) and flows into a thin yellowish liquid. A small portion of it volatilizes during the fusion, but after it is melted it may be kept in a common crucible at a faint red-heat for an indefinite time without subliming, or sinking through the pores of the vessel. Neither does it attack glass in any degree, but at this temperature is transparent and has a pearl-grey lustre which is very distinguishable. When cold it concretes into a yellowish, tough mass, transparent in thin laminæ, flexible, which may be easily cut with scissars, and a good deal resembles *horn* in its appearance, whence the term *horn silver*, or *luna cornea*, which properly only belongs to it in this state, but is indiscriminately used for the muriat in any state, and which we shall here retain. Luna cornea when cooled in mass may be turned on the lathe, and snuff boxes have been made of it by the curious. When cooled slowly it has a strong tendency to the octohedral form.[x] A strong red heat volatilizes it totally in very dense white fumes.

[w] Proust.

[x] Ibid.

Muriat of ſilver when newly precipitated is of a delicate white colour, but this changes very ſpeedily and in a very ſtriking manner to a grey ſlate colour by a ſhort expoſure to light, which is an uſeful mark of diſtinction between this and many other metallic precipitates. The change however is quite ſuperficial. In a ſtrong ſunſhine it takes place very rapidly, and it was diſcovered by Scheele that when the rays are ſeparated by a priſm and thrown ſeparately on the muriat, the blackening took place in twenty-four ſeconds in the violet ray, and in an increaſing diſtance of time in the ſucceſſive colours of the ſpectrum, ſo that in the red ray, no leſs than twenty minutes were required. Mr. Ritter of Jena has ſince found that as there are inviſible heat-making rays exiſting on the outſide of the priſmatic ſpectrum beyond the red ray, (diſcovered by Dr. Herſchell, and mentioned under the article *Caloric)* ſo there are inviſible rays on the other ſide of the ſpectrum, beyond the violet ray, which poſſeſs in the higheſt degree the chemical effects known to be produced by ſenſible light, and particularly that of blackening muriat of ſilver. This was alſo diſcovered about the ſame time by Dr. Wollaſton. Mr. Ritter alſo aſſerts that if the muriat already blackened in the violet ſide of the ſpectrum, be transferred to the red ſide, the whiteneſs is partially reſtored. Theſe very curious experiments however belong more properly to the ſubject of light.

As the muriat of ſilver is produced in a great variety of analytical experiments, and ſerves to determine the quantities both of muriatic acid and of ſilver in any compound, it becomes of great importance to determine with perfect accuracy the proportion of the conſtituent parts of this ſalt. Fortunately its compoſition is ſo uniform, its inſolubility in water is ſo perfect, and the neceſſary proceſſes of edulcoration are ſo eaſy, that there is an almoſt abſolute agreement in the reſults of the experiments of different chemiſts, regard being had to the circumſtances of drying and reduction. It has been found by Klaproth that 100 parts of pure ſilver diſſolved in nitric acid, and precipitated by common ſalt, yield about 133 parts of luna cornea, dried at a heat ſuperior to that of boiling water, but ſhort of its melting point, that is to ſay, thoroughly deſiccated, but without the volatilization of any of its conſtituent parts. Other chemiſts agree very cloſely with this reſult, and from the average of thoſe that appear entitled to the moſt confidence, we may eſtimate 100 grs. of luna cornea thoroughly dried but not melted, to contain 75.235 grs. of ſilver.[y] The remaining 24.765 grs. therefore conſiſt of muriatic acid and oxygen. Of the latter, it is eſtimated by Prouſt that 100 parts of ſilver take about 9.5 during ſolution in nitric acid, and the metal probably exiſts in the ſame ſtate of oxygenation in the muriat. If this is correct, the oxygen in 100 grs. of dry luna will be about 7.15 hence the component parts will be

Muriatic acid	17.615
Silver - -	75.235
Oxygen - -	7.15
	100.000

It ſhould be obſerved however that Kirwan and other chemiſts eſtimate the quantity of oxygen taken up by 100 grs. of ſilver, to be as much as 10.8, which would make the oxygen in 100 grs. of luna cornea to be about 8.1, and would reduce the muriatic acid to about 16.6. The proportion of ſilver, however, is more certainly aſcertained, and the above eſtimation may be ſafely taken without danger of any material error.

Muriat of ſilver loſes ſome weight when paſſing from the ſtate of perfect deſiccation to fuſion, but when melted it may be kept in fuſion without further loſs, the heat not being raiſed much higher than neceſſary. Dr. Thomſon found 132.35 grs. of luna cornea dried at 400° (the product of 100 grs. of ſilver) to be reduced to 128.67 grs. by ſimple fuſion, whence 100 grs. of fuſed luna cornea may be eſtimated to contain 77.36 grs. of ſilver inſtead of 75.235 as given above.

Muriat of ſilver is nearly if not abſolutely inſoluble in any acid except the muriatic, but this acid diſſolves it without difficulty when heated, and the muriat may then be obtained in octohedral cryſtals. If this ſolution be diluted with water the muriat ſeparates in its uſual form.[z] Luna cornea is ſoluble in pure ammonia without decompoſition, and when this ſolution is evaporated in the temperature of the atmoſphere, the muriat is left either in ſmall cubes or in glittering ſcales, the latter of which reſemble very cloſely the ſuperficial ſcaly incruſtation of the native luna cornea.[a] But if the ſolution is evaporated by artificial heat, the firſt particles that fall to the bottom are the fulminating oxyd, and when ſhaken in the ſlighteſt degree will detonate with extreme vio-

[y] Kirwan on Mineral Acids, &c.

[z] Prouſt. [a] Klaproth.

lence,[b] so that this dangerous experiment should be performed with the utmost caution.

There are various methods of reducing muriat of silver. The most frequently used is by carbonat of potash. For this purpose rub the dry muriat with about twice its weight of common pearl-ash, put it into a crucible, cover it with a little more pearl-ash, and put it into any furnace capable of giving a silver-melting heat. The crucible must be large enough to hold about twice the bulk of the materials employed. Apply heat gradually, and the mass will first melt and then give off a great quantity of gas with much intumescence, and become quite black. Whilst this is going on the heat should not exceed a moderate redness, otherwise part of the contents are very liable to spurt out by the effervescence, after which it may be raised to a full white red for a few minutes, and the crucible is then to be taken off, struck gently on the outside with a hammer, to shake down all the scattered globules of metal, and cooled very gradually. On breaking it, if the reduction is well performed, it will be found to contain a clean saline mass consisting of muriat and carbonat of potash fused into an uniform substance, and at the bottom will be a button of perfectly pure silver, beautifully white and resplendent, without the least discoloration on the surface, and easily detached from the saline mass above it. It requires some practical skill to know how long to continue the fusion, for as there is a great excess of carbonat of potash, the operator need not wait till all effervescence is over, but yet if the heat is urged too briskly some of the luna cornea is volatilized along with part of the alkali. However, where the mere object is to procure a quantity of pure silver from luna cornea, it is not difficult to do it without incurring any material loss; but when it is required for the purpose of analysis to obtain *all* the silver from a given quantity of the muriat, more precaution is requisite. In examining the crucible and saline mass after reduction, minute globules of silver are sometimes found either dispersed through the mass or more commonly sticking to the sides of the crucible. In the former case they arise either from not heating the mixture sufficiently, or (what is more probable) from cooling it too suddenly, whereby the silver, which becomes solid much sooner than the salt, in the moment of congealing, spurts up some globules, which penetrate and are detained in the fluid above. When the globules stick to the crucible it is often owing to some roughness in its sides, which may be prevented by giving it a coating of borax by melting a little of this salt in it before the reduction. Small quantities of luna cornea may also be reduced in a dry phial set in sand instead of a crucible, by which all the silver may be collected very accurately. Carbonat of soda answers as well as potash. Most of the effervescence may be prevented by employing the caustic alkalies instead of the carbonated, but this is expensive in the large way. Whatever care is taken in the reduction, it is seldom that quite 75 parts of silver can be recovered from 100 of luna cornea, so that a small portion is volatilized.

Luna cornea may also be reduced by mercury. This method was first discovered by Marggraf, who has also given the following interesting experiments on the subject.[c] This excellent chemist first observed that spirit of sal ammoniac made with sal ammoniac and litharge, (or pure ammonia dissolved in alcohol) dissolved luna cornea in the cold; and a solution was equally effected by spirit of sal ammoniac prepared from salt of tartar and sal ammoniac, (or *carbonated* ammonia dissolved in alcohol) and on adding to the latter solution six times as much mercury as it contained of luna cornea, on the next day a fine Arbor Dianæ was found in the mixture, which was a perfect amalgam of mercury and silver. This led him to attempt the reduction of luna cornea more directly, which he performed in the following way. Put in a glass mortar, one part of luna cornea, add to it about twice its weight of dry carbonated ammonia with just sufficient water to bring it to the consistence of soup, and rub them together for a quarter of an hour, during which the mixture will swell and effervesce a little: then add six parts of the purest mercury revived from cinnabar, and continue the rubbing for some hours, during which the mixture will first become of a blackish grey, and a perfect amalgam of mercury and silver will be formed. Then add a quantity of water, which will become milky, and pour it off into a separate vessel before the white powder suspended in it has subsided, leaving the amalgam in the mortar. Wash the latter repeatedly with water, and continue rubbing, till all the white powder is rinced out, and the water returns clear from off the pure amalgam. The white powder is submuriat of mercury, very similar to calomel, and the silver has passed into the mercury of the amalgam, whence it may be recovered by dis-

[b] Proust.

[c] Hist. de l'Acad. de Berlin for 1747.

tilling it *per se* in a retort, with a heat gradually increased to redness. A very small portion of the silver however remains in the white powder, which may be recovered by sublimation, in which the sub-muriat of mercury rises pure, and a grey powder remains, which melted with borax gives a small globule of silver. In this way Marggraf recovered almost the whole of half an ounce of fine silver which was first converted into luna cornea, for the amalgam left after distillation half an ounce of silver wanting four grains, and the small globule procured from the mercurial sublimate weighed 2½ or 3 grains more. He also observes that it is quite necessary to wash out the mercurial muriat from the amalgam before the latter is distilled, for if it is left in, the affinities are changed at a high temperature, and luna cornea and running mercury are again formed.

The same reduction of luna cornea takes place without the labour of rubbing, by putting it along with the carbonated ammonia and mercury in a retort, adding a good quantity of water, and distilling to dryness. There remains then in the retort the amalgam and sub-muriat of mercury, which are to be treated as above. The ammoniacal liquor which comes over may be saved for a future operation.

In all these processes it is always to be remembered that it is the *carbonated* and not the *caustic* ammonia which is to be employed, for caustic volatile alkali can never be heated with muriat of mercury without danger of producing the very formidable fulminating powder, which will be presently described.

Muriat of silver may also be reduced by fusion with lead. Kunckel recommends mixing the muriat with thrice its weight of granulated lead and melting the mixture in a retort. It then will contain two distinct substances, the upper is muriat of lead, and the lower metallic silver, alloyed however with a good deal of lead, which must afterwards be separated by cupellation. Proust observes in this process that two parts of lead are quite sufficient, but there is always some loss of the silver after cupellation, as it never exceeds about 74 parts from 100 of the luna cornea. Several other of the metals will answer the purpose of the lead, but without the same advantages.

The habitudes of muriat of silver with iron and its salts are important. If the muriat is boiled in an iron vessel with water, and some bits or filings of iron, a powder gradually collects at the bottom, which is metallic silver, and when heated with borax, melts into a pure button of metal. The water contains muriat of iron. The decomposition is known to be compleat when the powder of silver is not blackened by exposure to the sun. This process which is given by Sage, was repeated by Proust with the following results. A hundred parts of dry luna cornea (containing 75¼ per cent. of silver,) were mixed with as much iron filings, and boiled with water for some time in a silver vessel. The powder remaining was then well washed and mixed with mercury to collect the silver. This amalgam left after distillation 72½ parts of silver, and on adding more mercury to the powder 2½ more of silver were left, making in all 75 per cent. Zinc filings will answer as well as iron.

Luna cornea is not decomposed by sulphat of iron, but it is reduced by iron in the act of solution in dilute sulphuric acid, when in contact with it. Muriatic acid and iron have the same effect. We may here also make a few observations on the mutual action of sulphat of iron and metallic silver.[a]

When the red sulphat of iron (or that in which the metal is fully oxygenated) is *boiled* with pieces of silver, a portion of the metal is dissolved so as to give a luna cornea with salt, and the sulphat is reduced to the state of the green, or *sub-oxygenated*, sulphat. But on keeping the solutions together for a time bright scales of metallic silver form in them (probably with the assistance of the light) and the sulphat returns to its original state of compleat oxygenation. On the other hand a cold solution of the green sulphat mixed with sulphat of silver, decomposes the latter and metallic silver precipitates. Hence it appears that at a common temperature the green sulphat takes oxygen from the salts and oxyds of silver, but when the heat is raised the reverse takes place, and the red sulphat yields oxygen to silver. In the latter case however the affinity of the oxyd of silver for sulphuric acid must assist in the decomposition.

Muriat of silver is liable to be formed whenever silver remains for a length of time in contact with any muriatic salt. Thus Proust found silver dollars deeply corroded and partly converted into muriat, by lying for many months at the bottom of the sea on the coast of Spain.

The acetous acid has no action whatever upon pure silver, but it combines easily with its oxyd. Acetite of silver is readily formed by adding acetite of potash to nitrat of silver, or more simply by boiling this acid on the carbon-

[a] *Proust.*

ated oxyd of silver. In this case the solution very readily begins to crystallize the moment it cools, and forms long needled crystals, but at the same time a part of the salt is reduced, and the mass of crystals and liquor is fouled with a quantity of black powder of reduced silver, which however soon subsides. The clear acetite when kept in a bottle exposed to the light is also partly decomposed, and the glass soon becomes lined with a brilliant silvery film. Acetite of silver is of use in chemical analysis, particularly in examining mixtures of the nitrats and muriats, where the operator wishes to ascertain and separate the muriatic acid without adding any extraneous nitric acid, which would be the case if the nitrat of silver were employed.

When silver is treated with nitrous acid and alcohol, a white powder is deposited, which fulminates with extreme violence, and which, from the analogy with the fulminating mercury produced in the same way, is probably an oxalat of silver.[e] This preparation was discovered by Mr. Howard, in his attempts to communicate to other metals the same fulminating property which he had given to mercury, and is prepared in the same manner as has been described in the article *Mercury*.

Mr. Cruickshank in repeating this experiment, dissolved 40 grains of silver in 2 ounces of strong nitrous acid diluted with as much water, and on heating the solution with 2 ounces of alcohol, he obtained 60 grains of a white powder which fulminated violently. Brugnatelli has given the following method of preparing the same.[f] Put 100 grains of lunar caustic in a glass, and pour on them first an ounce of alcohol, and then as much concentrated nitrous acid. The mixture grows hot, boils, and an ether is visibly formed, which flies off in vapour. By degrees the liquor becomes milky and is filled with small white flocculi. When the liquor has thickened by this precipitation, add cold distilled water to suspend the ebullition, otherwise the precipitate would be re-dissolved, then collect the powder and dry it with a very moderate heat. This is the fulminating silver, and amounts to more than half the weight of the lunar caustic employed.

One grain placed on a lighted coal detonates with a deafening report, if touched with the end of a glass tube dipped in sulphuric acid, or with the electric spark, so that in violence it greatly exceeds the fulminating mercury.

The combination of oxyd of silver with ammonia is remarkable for affording the most violently detonating substance yet known. This was discovered by Berthollet, and considering the multitude of experiments in which ammonia has been employed along with the salts of silver, it is rather surprizing that it was not sooner discovered by some serious accident.

This fulminating ammoniacal oxyd is prepared in the following way, according to Berthollet the inventor,[g] and the directions given by Dr. Higgins:[h] dissolve any quantity of silver, perfectly free from copper, in as little nitric acid, moderately dilute, as is sufficient, pour off the clear solution from any black sediment which may be left (and which is commonly gold) and add to it lime water as long as any considerable precipitate falls down. Edulcorate this precipitate, which is a brown oxyd of silver, and then lay it on several folds of filtering paper, or spread it out on a single paper laid on a smooth dry lump of chalk, and dry the precipitate thoroughly in the open air. Set this oxyd by for use in a well-corked phial. About $1\frac{1}{2}$ oz. is obtained from an ounce of fine silver. The caustic fixed alkalies may be used instead of the lime-water, but they do not act with so much certainty. This oxyd dissolved in ammonia, forms the fulminating powder. For this purpose add 10 or 12 grains of this oxyd to about half an ounce in measure of liquid ammonia, perfectly caustic and moderately dilute. This gives a snapping noise, and blackens the whole oxyd immediately, and dissolves either a portion of it only, leaving a black powder at the bottom, or, if more ammonia is used, the whole is dissolved. Pour the clear solution off from the black powder, if any, and expose it in a shallow vessel to the air. In ten or twelve hours a crystalline pellicle appears on the surface of the ammoniacal solution, which is the fulminating silver, and is composed of a congeries of black shining crystals. Take them out, whilst still wet, and lay them in separate parcels of not more than a grain or two on blotting paper, and let them dry in the air, carefully avoiding to touch them.

This fulminating powder has the following properties: even when still wet if it be pressed upon with a hammer or any hard body, it fulminates with extreme violence, but when dry, the touch of a slender wire or even a feather, or a heat of about 96°, is sufficient to make it explode. Even a moderate concussion of the air is sufficient, so that a heap may be exploded by the concussion of any other in its immediate neighbourhood. Sometimes too it will

[e] Phil. Trans. for 1800. p. 285.
[f] Phil. Journ. 8vo. vol. vii. p. 285.
[g] Berthollet, Ann. Chem. tom i.
[h] Higgins Minutes, p. 324.

go off in the hand, when carrying from one place to another, so that in fact when it is once dry, the operator should be prepared for the explosion at any time, even with the most careful handling. A momentary flash is visible at the time. If the ammoniacal solution poured off from the fulminating crystals is heated in a small retort (which however is a most hazardous experiment) bubbles of azotic gas are given out, and small opake crystals with a metallic splendour are formed, which fulminate violently when touched, even in the midst of the liquor, and the vessel bursts into an infinite number of fragments. When any of this solution touches the skin it blackens it for a time like nitrat of silver. The fulminating crystals when dry, appear to remain unaltered for a considerable time, for Fourcroy relates that he has seen them explode with their usual violence, after being kept for some months undisturbed.

It appears probable that there are two or three varieties of this ammoniacal oxyd of silver, such as, the black powder which subsides at first when less ammonia is added to the oxyd of silver than will dissolve it, the fulminating crystalline pellicle which first separates from the solution, and the black crystals which separate when the solution is boiled. The first of these, the black powder, is stated by Dr. Higgins not to have a fulminating property, but the precise nature of these compounds has been but little examined.

It requires considerable care to succeed in producing the fulminating silver. The metal should be quite free from copper, the oxyd produced by lime should be thoroughly edulcorated, and especially the ammonia should be quite free from carbonic acid. Carbonat of ammonia does indeed dissolve the oxyd of silver with some effervescence, owing to the escape of part of the carbonic acid, but with the remainder a triple ammoniaco carbonated oxyd of silver is formed, which will not fulminate.

Several serious accidents have happened in preparing this fulminating silver which shew the necessity of great precaution in the operator, and as all the circumstances in which the explosion is produced are not as yet known, he should on no account venture to prepare more than a few grains at a time of this dangerous compound. Dr. Higgins mixed together 24 grains of the oxyd of silver with a quarter of an ounce of water *saturated* with ammoniacal gas in a corked bottle, which produced a blue solution with the expulsion of some gas, and without the formation of any pellicle, and six hours afterwards, on shaking the bottle to compleat the solution of a little blackened oxyd which lay at the bottom, the whole exploded with excessive violence, the bottle was quite reduced to powder, and his hand was numbed as if with the blow of a heavy hammer. In this case it appears probable that this unexpected explosion arose, partly from using too concentrated a solution of ammonia, too large a quantity of silver, and especially from shaking the contents of the bottle. Another accident is mentioned in the Journal de Physique[i] where the preparation seems to have been conducted with perfect prudence and accuracy, and an ammoniacal solution was made, which contained apparently about five grains of the fulminating crystals, but on dipping a card into it to take out the crystals, the whole exploded with excessive violence, which had nearly deprived the operator of his sight. The only difference from the common way of operating in this case appeared to be that the crystals were allowed to remain in the solution twenty-four hours after mixture, instead of being taken out as soon as they appeared.

It has been already mentioned that this fulminating silver is also produced when *muriat* of silver is boiled with pure ammonia, and explodes in the act of formation, and hence arises another precaution in applying artificial heat to any mixture of ammonia and oxyd of silver free from carbonic gas.

Silver is capable of uniting with sulphur in various proportions. Artificial sulphuretted silver is a black brittle mass, like the native sulphuret. The utmost proportion of sulphur capable of uniting with silver is stated by Wenzel[k] to be 13 of the former to 87 of the metal. Yet the following experiment by the late Mr. Alchorne, seems to shew that the silver does not easily retain much more than half this quantity at a moderate red heat. Half an ounce (240 grains) of silver precipitated from the nitrat by copper was mixed with its own weight of sulphur, and put into a crucible with another inverted over it, and luted, leaving a small hole for the escape of the superfluous sulphur. On applying a red heat, part of the sulphur escaped and burned off at the hole. The fire was increased to a degree which was judged sufficient to melt the mass within, and kept up till the blue flame disappeared. When cold, a dark lead-coloured brittle button was

[i] Tom. 58, p. 362.

[k] Kirwan's Mineralogy, vol. 2.

found in the crucible, which was soft enough to be cut with the knife, and exactly resembled the vitreous silver ore. The silver had gained 20 grs. or $\frac{1}{17}$ in weight, whence the proportion of sulphur in this artificial sulphuret is about 7.7 grains in 100.

A sulphuret, or rather a hydro-sulphuret of silver is also formed whenever this metal is exposed to sulphureous vapours, or any liquid containing sulphuretted hydrogen. After a certain time the substance of the metal is deeply sulphuretted, and may be detached in brittle scales. But it takes a great length of time to effect this by mere exposure to sulphureous vapours.

The superficial *tarnishing* which silver plate undergoes when laid by for some time, or more suddenly, when in contact with animal matters, is probably owing to this change, but it long remains only superficial.

The instant precipitation of a black hydro-sulphuret in all the salts of silver produced by the addition of a liquid sulphuret or gasseous sulphuretted hydrogen, has been already mentioned.

Silver unites with phosphorus though weakly. Pelletier[l] obtained this phosphuret by mixing in a crucible half an ounce of silver in fine division, 2 drachms of powdered charcoal, and an ounce of vitrified phosphoric acid, and giving it a full heat for half an hour. On opening the crucible the fusion was compleat, and on cooling, many luminous jets of phosphorus came from the silver in the act of solidifying. The silver had gained a drachm in weight, had lost its ductility, had a granular and crystallized texture, and was brittle. It remained white, and soft enough to be cut by the knife. When melted on a cupel the whole of the phosphorus burned off, and the silver remained pure.

Some of the alloys of silver are important. This metal will unite with some metals perfectly and without losing its malleability; with others it forms a brittle white alloy, but with others it refuses to unite except in a very minute proportion.

Silver mixed with gold, dilutes its yellow colour more or less according to its quantity.[m] Gold with $\frac{1}{20}$ of silver is sensibly paler, and the debasement of colour proceeds pretty uniformly as the silver is increased. These mixtures are very malleable though somewhat firmer, harder, and more sonorous than either metal separately. In this respect, as in the colour, a little silver affects gold more than a little gold does silver. On account of the superior price and the alteration of colour, silver is never intentionally alloyed with gold, but a large portion of the American silver naturally contains a small quantity of gold, which remains as a fine black slime or sediment when the silver is dissolved in aqua fortis.

Homberg mentions in the Memoires de l'Acad. des Sciences for 1713 a curious experiment to shew that in certain circumstances a separation may take place between these two metals. He melted equal parts of gold and silver in a crucible with a little sea-salt and nitre for a quarter of an hour, and when cold, the gold was found at the bottom in one lump, but retaining about a sixth of silver, and above was the remainder of the silver in a separate button quite pure. He observes that this experiment only succeeds with nearly equal quantities of the two metals, and with a fire not too long continued. If this be accurate, there appears a point of saturation of one metal with the other respectively, but the experiment has not been repeated, nor does it agree with those authors who assert that the two metals produce an uniform alloy in any proportions.

The curious effect produced on silver by being alloyed with platina has been already described under the article *Assay*, p. 118, and that of *Platina*.

Copper is the metal usually employed to alloy silver in the vast quantity of this metal used for coin and plate of all kinds. The standard silver of this country is composed of eleven parts of silver and one of copper. In this proportion or even somewhat more of the alloy, the mixture remains nearly as white as pure silver, but is much harder, less fusible, and though it remains highly malleable and ductile so as to bear being extended into any shape, and wrought in a thousand different ways, it is certainly less ductile and malleable than a metal with less alloy, since such a finer metal is required to be used in making silver wire and leaf. On account of the hardness given by the copper alloy it is much better fitted to take a fine impression, and is therefore particularly useful in coining, and in all domestic implements.

An alloy of these two metals has been used in France for coinage for many years, and called *monnaie de billon*, in which the silver is from $\frac{1}{12}$ to $\frac{1}{4}$ of the mass, and which looks like

[l] Memoires, tom. 1.

[m] Lewis's Commerce of Arts.

half-whitened copper, or degraded silver. Being on the whole an injudicious compound it is mostly now laid aside. When silver and copper are in equal parts, the alloy is still very yellow, but may be united with about 4 or 5 per cent. of arsenic, and still remain very malleable, with the advantage of being much whitened by the mixture. Vauquelin[a] has also found that a larger dose of arsenic, does not increase the whiteness, but rapidly impairs the malleability, and when the arsenic amounts to 10 per cent. the alloy is so harsh and brittle as not to bear laminating.

Silver unites perfectly with lead apparently in every proportion, into an uniform malleable mixture, harder and whiter, and less fusible than pure lead, in proportion to the quantity of silver. This mixture is formed in the process of *Eliquation* (already described in this article) whence it appears that the affinity of silver for lead is superior to that of silver for copper. The necessity of this alloy to the process of cupellation in *assaying* and in refining silver has been already mentioned.

Silver and iron are generally reckoned entirely to refuse to unite in any proportions, and it is certain that when they are melted together, they form, on cooling, two perfectly distinct and separable buttons, the iron at top, and the silver beneath it. Yet a certain degree of alloying takes place as is proved by the following curious experiment of Guyton on this subject.* In a crucible lined with charcoal, 15 parts of pure silver, reduced from luna cornea, were mixed with as much fine iron filings, and a flux composed of glass, charcoal dust, and a little borax. This was kept for an hour in a heat of 150° to 155° *Wedgewood*, and on cooling, a button was found with some traces of crystallization on the surface, but which separated most accurately into two buttons of very different composition. A part of the lower button, dissolved in nitric acid, gave only a white precipitate, and not a blue one, with prussiat of potash, and appeared to be perfectly pure silver, but the metal was found to be pretty strongly magnetical, and therefore contained a very small portion of iron, which was estimated by Coulomb to be about $\frac{1}{320}$. The upper button, which appeared to be pure iron, was excessively hard, very difficultly frangible, and when dissolved in nitric acid gave a copious precipitate of luna cornea with salt, the quantity of which indicated an alloy of about $\frac{1}{80}$ of silver.

Silver unites with bismuth, zinc, antimony, and some other of the brittle metals, forming brittle alloys which have not been much examined, and are of little importance.

The affinities of the oxyd of silver for the different acids are in the following order: the muriatic, oxalic, sulphuric, phosphoric, nitric, arsenic, fluoric, tartareous, citric, acetic, and carbonic.

SILVERING, *the Art of.*

This art consists in covering the surface of substances with a thin coating of silver. There are two motives for this; in the first place, the superior beauty of silver to that of the cheaper metals; and in the second place its superior wholesomeness to copper, brass, or lead, for culinary purposes on account of its not being acted upon by vinegar and other weak acids.

As an ornament, silver is far inferior to gold, from its great liability to be blackened by sulphureous vapours, which renders frequent cleaning absolutely necessary; hence it is inapplicable to the purpose of architectural decoration, and is scarcely ever applied except to utensils and ornaments of metal. From the frequent necessity of friction for the purpose of removing the tarnish of silver it is necessary that it should be much thicker than the most solid gilding, otherwise, after a short time, the silver will be worn off the most prominent parts, discovering to view the copper or brass beneath.

The only metals that are silvered are copper, brass, and very rarely iron.

There are three modes of silvering, namely, by silver amalgam, by muriated silver, and by silver in substance.

1. *Silvering by amalgamation* is thus performed:

To a solution of nitrated silver add some plates of copper which will throw down the silver in its metallic state, and very finely divided; scrape it from the surface of the copper, wash it well and dry it. Of this powder take half an ounce, of common salt and sal ammoniac 2 ounces, and of corrosive sublimate one drachm, rub them well together, and make them into a paste with a little water. Then take the vessel to be silvered, and clean it by means of a little very dilute aquafortis, or by scouring it with a mixture of common salt and tartar. When it is perfectly clean, rub it with the above-mentioned paste till it is entirely covered with a white metallic coating; this coating is an amalgam produced by the de-

* An. Chim. tom. 39, p. 265.

[a] Ibid. tom. 43.

composition of the corrosive sublimate by means of the copper, to the surface of which it applies very closely and expeditiously. The copper being thus silvered over is to be washed, dried, and afterwards heated nearly red, in order to drive off the mercury; the silver remains behind adhering firmly to the copper, and capable of being highly polished.

2. *Silvering by luna cornea.*

Prepare the luna cornea in the usual manner by pouring a solution of common salt into nitrat of silver as long as any precipitation takes place, and boiling the mixture; the white curdy matter thus obtained is to be mixed with three parts of good pearl-ash, one part of washed whiting, and somewhat more than one part of common salt. The surface of the brass being cleared from scratches is to be rubbed with a piece of old hat and rotten stone to remove any grease, and then is to be moistened with salt and water, a little of the composition being now rubbed on with the finger, the surface of the metal will presently be covered with silver. Then wash it well, rub it dry with soft rag, and as the coat of silver is extremely thin, cover it with transparent varnish to preserve it from tarnish. This kind of silvering is very imperfect, and is only used for the faces of clocks, the scales of barometers, and similar objects.

3. *Silvering by Silver in Substance.*

There are three ways of performing this. The first is by mixing together 20 grs. of silver precipitated by copper, 2 drachms of tartar, 2 drachms of common salt, and ½ a drachm of alum; this composition being rubbed on a perfectly clean surface of copper or brass, will cover it with a thin coating of silver, which may afterwards be polished with a piece of soft leather.

A still better way is that which is called French plating, which consists in burnishing down upon the surface of the copper successive layers of leaf-silver to any required thickness. In this the silver has much more solidity than in any of the former, but the process is tedious, and the junctures of the leaves of silver cannot always be entirely concealed.

The English method of plating (in those works to which it is applicable) appears to be the best of all. It is thus performed: one of the surfaces of an ingot of copper is rendered quite smooth and clean, and is sprinkled over with glass of borax; upon this is laid a plate of fine silver, about $\frac{1}{12}$ of the weight of the copper and the two are carefully bound together by wire; the mass is now exposed to a full red heat which melts the borax and causes the silver to adhere to the copper; the ingot is now passed through a rolling press, and formed into a plate; both the silver and copper extending uniformly during the whole process, at the conclusion of which the two metals are inseparably fixed to each other.

SINOPLE. See JASPER.

SIZE. See GELATIN.

SKIN. For the preparation of the skin of animals for the purposes of manufacture, see the article LEATHER.

SLAG. Is a technical term used among smelters and workers in minerals, to express any hard vitrescent generally coloured and opake mass; produced by the fusion of any stony or metallic mixture. It generally consists of the gangue or matrix of the ore, together with any saline or earthy flux that may have been used. Thus the *slag* of iron founderies is for the most part composed of the earthy part of the ore, of the lime used as a flux, and the whole deeply coloured with a part of the oxyd of iron which has escaped reduction. A *slag* differs from a *scoria* in being more dense and more compleatly vitrefied, whereas the scoria or dross is lighter and porous. When the slag is very opake and heavy, it contains a considerble quantity of metallic oxyd so that in improved smelting works it is often worth while to work over again with fresh reducing matter the slags of former operations conducted less skilfully. In some parts the slag of founderies is broken into lumps, and used for mending roads, for which it makes an excellent material when a little worn down, being very hard, and impenetrable by water.

SLATE. See THONSCHIEFER.

SMALT. See COBALT.

SMARAGD. See EMERALD.

SMELTING, *Schmeltzung*, Germ. is the reduction of metallic ores and fusion of metals in the large way.

SOAP. *Seife*, Germ. *Savon*, Fr.

A soap may perhaps be defined to be a chemical union of any oily with any saline matter whereby the oil acquires a solubility in menstrua with which it naturally refuses to unite.

In this extended sense many compounds are called *saponaceous* or *soapy* which are natural or artificial mixtures of the saline and the oily or resinous; thus bile is termed a saponaceous fluid because it contains a natural resin and an alkali in intimate union, and miscible to any

extent with water. Adipocire likewife is a faponaceous fubftance, being diffufible in water, and to a certain degree foluble in it by means of the ammonia united to the oily matter. Milk on the other hand is not faponaceous though it contains an oil diffufed in a watery ferum, as the intermede by which this is effected is (to all appearance) not faline, but albuminous and infipid.

But the term *foap* is in common language reftricted to that combination of oil with alkali which is extenfively ufed for domeftic and manufacturing purpofes.

The materials ufed in foap making are, oil of any kind, vegetable or animal, and fixed alkali, either foda or potafh. Thefe (that is, oil and alkali,) enter into the compofition of every foap, and befides, lime is effential to give the alkali the requifite degree of caufticity: common falt is alfo employed in moft of the potafh-foaps, for a purpofe which will be afterwards mentioned.

The general procefs for foap-making is on the whole very fimple, and confifts, firft in making a cauftic or partly cauftic ley with the alkali and lime; next of boiling the ley with the oil till they are perfectly united into a fmooth uniform foap; and laftly of drying the foap till it is become of a proper confiftence for ufe. But though the general procefs is fimple, and fuccefs to a certain degree may be infured by any one who puts the proper ingredients together in the plaineft manner, there are a confiderable number of precautions and many minute attentions required to make the beft and moft perfect article with the greateft economy. Moft of thefe are only to be learnt by practical experience, but it will be proper in this place to enlarge upon the different fteps and varieties of this very important manufacture.

The fimpleft, and on the whole the moft beautiful foap, is the fine white foap prepared from olive oil and foda, extracted from the beft barilla, which is manufactured very largely in the countries where the olive grows, efpecially in the South of France, (for which Marfeilles is the moft celebrated) in fome parts of Italy, and in Tripoli, which laft is often of excellent quality and cheap, and is largely imported into various parts of Europe. A fimilar, but more expenfive foap is made of foda and oil of almonds, for medicinal purpofes. What is called in this country *Windfor foap* is of this kind, with either of the above mentioned oils.

But the common foaps ufed in England are made, as to the oil, principally of tallow and any other candle or kitchen greafe, and as to the alkali, of potafh, pearlafh, and other kinds of the vegetable alkali, with or without a mixture of barilla, according to the price of the latter; and on account of the peculiar ufe of common falt in moft of them, the procefs is fomewhat more complicated. The ordinary *yellow* foap alfo differs from the *white*, in containing a portion of rofin, and fometimes alfo is fcented with palm oil.

We fhall firft defcribe the method of making the white olive oil foap, which with fome little variations is practifed at Marfeilles, and other parts of France.[a b c]

To make about 1000 lbs. of this foap the materials requifite are 500 lbs. of good barilla, 600 lbs. of olive oil, (of which the inferior forts are ufed, and anfwer full as well) and 100 lbs. of quicklime. The barilla being firft broken down in a mill to a coarfe powder, and the lime flacked with a little water and fifted, they are ftirred together and put into a vat with a perforated bottom, and covered a few inches with water, to extract the alkali. In two or three days the ftop-cock at the bottom of the vat is opened, and a clear, nearly cauftic, ftrong ley of foda is drawn off. It fhould be fo much concentrated that a frefh egg will fwim in it, and is about of that fpecific gravity that eleven drams of it in weight will only fill a bottle which would contain an ounce or eight drams of water. When all this ley is drawn off, the cock is turned, frefh water is poured on the materials, and after ftanding for fome hours the ley is drawn off as before. This fecond ley is ftill very alkaline, but much weaker than the firft. A third ley is generally prepared in the fame way, which is ftill weaker. The materials, which are now exhaufted of their alkali and confift of carbonat of lime with the impurities of the barilla, are ufed as manure.

The oil is then poured into the boiler (which is a large copper veffel, fet in brick work, and heated by a furnace under its bottom) and with it the third or weakeft ley, and the fire is kindled and raifed till the liquor begins to boil. The materials are conftantly ftirred to haften the union between the oil and the alkali, and the reft of the third and the fecond leys are added gradually. As foon as the liquor in the boiler begins to get hot it turns milky, and after fome hours boiling will be found to become more tenacious and thicker. Then a fmall portion of the firft or ftrongeft ley is thrown in, and this

[a] Memoires de Pelletier. [b] Encycl. Arts and Metiers, article *Savon*. [c] Beaumé Elemens de Pharmacie.

addition is continued at intervals during the boiling till the greater part of it is used, but some must be reserved to finish the operation. The liquor becomes more and more tenacious, and the tough saponaceous part begins to separate from the clear watery liquid below. This is a sign that the process is going on well, and the boiling is continued till the whole contents of the copper are visibly separated into two parts, the tenacious white soapy mass above, and the clear liquor below. When this is compleat, sometimes it is the custom to stir in with poles a few pounds of common salt, which still further promotes this separation, and gives the soapy mass a pasty or granular consistence: but this addition (which is essential in the potash soaps) is not necessary in those with soda, and may be omitted. The fire is then drawn, and the contents of the boiler allowed to remain at rest for some hours that the soap may collect more compleatly, after which a cock is opened at the bottom of the boiler, and the clear liquor drawn off. This latter is coloured and is now no longer caustic, but as it still contains some alkali, it is mixed with the weaker leys and fresh lime, and reserved for future boilings. To the stiff soapy paste left in the boiler a little water or weak ley is then added, and the fire lit again, and when it has become fluid the reserved part of the first ley is added, and the whole brought to boiling. The soap being now nearly perfect, small portions of it are taken out with a trowel and set to cool on a bit of slate, and by the degree of stiffness which it takes when cold the experienced workman judges when it is boiled enough. If it still sticks to the fingers and does not appear stiff enough, more ley must be added, and the boiling continued till it is brought to the proper state. The fire is then again taken out and the clear liquor drawn off as before after remaining at rest for a few hours. The fire is then again raised, and the soap is again melted with a little water to wash out the adhering alkali, after which it is allowed to cool till it is fit to be taken out and *framed*. The frames are wooden troughs with a moveable bottom, into which the soap is poured while still fluid, and allowed to remain for three or four days till it is stiff enough to be handled without sinking in. The soap is then taken out and cut into long oblong slices with a brass wire, and kept for some time in an airy room till it has become of the requisite hardness, and is then fit for sale. According to the valuable memoirs on this subject by Pelletier, Darcet, and Lelievre, above quoted, 3 lbs. of oil will make 5 lbs. of soap of the proper degree of dryness for use, but it continues to lose weight by keeping, so that when quite dry the above quantity is reduced to little more than 4 lbs. On the other hand when kept damp or used too soon, more than twice this weight may be made of the same materials.

Such is the usual way of making this kind of soap, which consists of a gradual incorporation of the oil with the alkali by the assistance of heat, beginning with a weaker ley and concluding with the stronger. It is said however that some of the Marseilles manufacturers use the whole alkali at once, and succeed very well in this way; nor is it easy to say why this graduated strength of alkali and these repeated interruptions of the process during the coolings and settlings are required, and why it might not all be made economically by one continued boiling. Nevertheless, the interrupted method seems to be that which is by much the most commonly used, and probably experience would prove its utility in the large way.

It is not essential to employ heat in producing a good soap, for the union between the oil and alkali will be perfect by a sufficient length of time of digestion if the ley be strong enough. Thus a very pure soap is sometimes made for medicinal purposes in the following way:[d] mix in a marble mortar or any vessel not metallic, any quantity of olive oil with half its weight of a strong ley of caustic soda. The oil should be previously melted in case it has become clotted by age. Stir them well together and they will immediately unite into a thick white mass, and continue the stirring for some minutes several times a day for about a week, or till the soap is stiff enough to be put into wooden frames in the usual way. Let it remain in the frames for three or four days till it has considerably hardened, and then cut it in slices and expose it to a free current of air in a dry room till it is compleat. This soap has at first a very strong lixivial smell, and a violently acrid taste, both of which go off by exposure to the air, but it takes nearly a month before the taste is mild or merely saponaceous.

Before we describe the manufacture of the other kinds of soap we may give in a few words the results of a series of valuable, and apparently accurate, comparative experiments on the soaps made with soda and a variety of oily substances, which were undertaken by Pelletier

[d] Beaumé.

and his colleagues. The quantity of the oily substance in each instance was 3 lbs. and the method pursued was nearly that which has been described as followed in the large way.

Olive Oil. 3 lbs. (avoirdupois) of this oil produced 5 lbs. of pure white soap in that state of dryness as to be fit for sale. After keeping for two months it lost an ounce more in weight, and was then quite dry, hard, and of an agreeable smell.

Oil of Almonds. 3 lbs. of this oil gave an excellent soap in every respect equal to the former, but after two months weighing only 4½ lbs.

Suet. The animal fats are much less used in France for soap-making than in this country, but the soap which they give is in every respect as good as that from olive oil. The precaution used in oil soap-making of employing the weaker ley at first, and gradually proceeding to the stronger, was not found necessary in this case. 3 lbs. of suet gave 5 lbs. of perfectly hard soap after keeping for three months and a half in a dry place.

Lard. 3 lbs. of lard gave 4 lbs. 14 oz. of dry hard soap after keeping for three months. In this and the former experiment the spent ley which separated from the soap, contained a quantity of animal gelatine.

Rancid Butter. A quantity of stale salt butter was boiled with water to extract the salt, after which 3 lbs. of it were weighed out and treated with soda in the usual manner. From the above quantity a white soap was obtained with ease, which the day after it was made weighed 11 lbs. and still retained some of the bad smell of the butter, and on keeping for two months it still weighed 7 lbs.

Horse Oil. A good deal of grease is prepared near Paris from horse flesh, by boiling. Of this, 3 lbs. gave 5 lbs. of good hard soap without any unpleasant smell, after keeping for two months.

Colesced Oil. Colesced, hempseed, linseed, rape, and many other common vegetable oils have a strong unpleasant smell and taste, so as not to be used in food, but they are employed largely in the state of oil for several purposes of manufacture. In general they are not much used for the *hard* soaps with soda, but a good deal of soft soap is made of them in Flanders and Holland, with pearl-ashes, as will be presently mentioned. In the above experiments they gave the following results.

3 lbs. of colesced oil treated as above with soda gave on coming out of the frame, only 5 lbs. of soap, which was yellowish grey, and still smelled strongly of the oil. On keeping for three months it was reduced to 3 lbs. 12 oz. and was tolerably hard, but by no means equal in this respect to olive oil, kept the same length of time.

Rape Oil. 3 lbs. of this oil gave also a yellowish grey soap, which after keeping for three months gave 4¼ lbs. of a good soap, sufficiently hard.

Beech-mast Oil. 3 lbs. of this oil gave a grey strong smelling soap, which after three months, weighed 4 lbs. 10 oz. and was still pasty, and stuck to the fingers. This oil therefore can only be used in mixture with others that give a harder soap.

Hemp-seed Oil. This is one of the most valued oils for the soft soaps, but will not answer for the hard. 3 lbs. gave after due boiling, a green soft saponaceous mass, which became pasty on any addition of water. After two months it weighed 4½ lbs. and hardened a little, but not sufficiently to be used in common washing.

Linseed Oil. 3 lbs. of this gave 5 lbs. of soap on coming out of the frames, which was greasy, pasty, and adhesive, with a very strong smell, and softened speedily on any addition of water. In two months it lost half a pound of its weight, but remained pasty and adhesive.

Whale Oil. This, and other kinds of fish oil, unites sufficiently well with soda, and forms a deep red-brown soap of tolerably hard consistence; but this soap has the inconveniences of long retaining the offensive smell of the oil, and being too readily softened by water, which unfit it for domestic purposes, though it may be used in bleacheries, &c. where the smell may be dissipated by long exposure to air. 3 lbs. of this oil gave 4½ lbs. of soap, after keeping for two months. Ling and seal oil soap have nearly the same properties and inconveniences.

All the above experiments were repeated with the crystallized carbonat of soda instead of the barilla of commerce, which was employed in the first set of experiments, and the respective results so nearly agreed with the former that a particular enumeration of them is needless. In these latter 3 lbs. of carbonat of soda, rendered caustic by 1 lb. of lime, were used for 3 lbs. of the oil; but in manufacturing in the large way the experimenters conceive that 80 parts of the alkali would be sufficient for 100 of the oil.

The olive oil, Marseilles, and other soaps are sometimes artificially *marbled* or streaked

throughout their whole ſubſtance with red or blue veins. This ſoap is harder than the white ſoap of the ſame materials becauſe it requires to be dried to a greater degree to take the marbling. This is performed by adding to the ſoap, as ſoon as it is compleatly made and ſeparated from the ſpent ley, a freſh quantity of ley and immediately after a ſolution of ſulphat of iron. A decompoſition between the two takes place, and a black oxyd of iron is ſeparated which is entangled within the liquid ſoap. The boiler is then cooled, and the ley which ſettles is drawn off, after which the ſoap is again melted. A workman then ſtands over the boiler and ſtirs the ſoap with a wooden inſtrument whilſt another throws in at intervals a quantity of colocothar or brown red oxyd of iron, ground up with water into an uniform liquid. This difuſes both the oxyds through the ſoap, which is then cooled and framed. There appears to be ſome manual dexterity required in ſtirring theſe ingredients together, ſo as to diffuſe the marbling ſufficiently through the maſs without mixing it compleatly.

All the ſoaps which we have hitherto mentioned are made with ſoda in one form or other, which alkali appears too to have been of the moſt antient uſe in ſoap-making; but there is another ſpecies in which the ſole alkali is the vegetable in the form of pearl-aſh, pot-aſhes, wood-aſhes, and the like, and in which no common ſalt is employed. Theſe potaſh ſoaps differ eſſentially from the others in remaining always ſoft and paſty however long they are kept. On this account they are not employed in common domeſtic uſes, but are chiefly uſed in ſcouring wool and other purpoſes of manufacture. However as they are perfect ſoaps, and entirely ſoluble in water, they may be partially employed in rendering water ſoapy for any purpoſe of cleanſing.

Soft ſoap is always coloured, generally of a brown or deep green, which however only depends on the nature of the oil uſed, for with olive oil it is white. It is much ſtronger and more acrid than the hard ſoaps, but in other reſpects it has the ſame chemical properties. The conſiſtence ſhould be that of a tenacious paſte or glue even in the hotteſt ſummer, and it ſhould melt readily in water forming a white and light froth. The mode of manufacture of this ſoap differs in this eſſential particular from the other, that no ſeparation takes place between the ſoap and the ſpent ley as in the ſoda ſoaps, but the whole contents of the boiler after ſufficient boiling and evaporation are converted into ſoap; neither is there any of the proceſs of framing and drying. A good deal of practical ſkill alſo (more than can be learnt from books) ſeems to be required in producing the proper union between the oil and alkali, and the proceſs appears liable to ſudden and often unaccountable failures, from the refuſal of the materials to unite with ſufficient intimacy, or from their diſunion after having already combined.

The manufacture of the beſt ſoft ſoap in Flanders and Picardy is thus deſcribed.[e] The oils uſed in theſe works are linſeed, hemp, poppy, coleſeed, and rape. Of theſe the two laſt are the cheapeſt and leaſt eſteemed. Fiſh oil alſo anſwers perfectly well, but the offenſive ſmell of the ſoap made from it is ſo permanent that its uſe is forbidden. The alkali is generally Dantzic, or Ruſſian pearl-aſh which is mixed with lime and lixiviated, till a ley ſtrong enough to bear an egg is obtained, and only one degree of ſtrength is uſed except reſerving a weaker ley for occaſional dilution of the ingredients. The boilers are the ſame as for hard ſoap, and ſhould not be filled more than half-full, on account of the great riſing of the contents whilſt they are incorporating. The proportions of the materials are on an average about 30 parts of oil to 40 of ſtrong ley, which yield about 65 parts of ſoap. The management of the boiling and gradual addition of the ley to the oil require conſiderable attention, and if it has ſucceeded properly, the oil and alkali unite into an uniform gluey ſaponaceous maſs, after which the boiling is continued till enough of the watery part has evaporated to leave the remainder of the proper conſiſtence when cold, which is known to be the caſe when a ſample taken out and cooled does not ſtick to the fingers and draw out in threads, but remains brown, ſomewhat ſtiff, and granulated. The boiler is then entirely emptied, and the ſoap is barrelled for ſale.

When the boiling has not been continued long enough, the ſoap is apt to ferment, and ſpoil by keeping.

Soap is manufactured in this country principally from tallow or any other fat; and the alkali employed is either barilla or pearl-aſh, or a mixture of the two, according to the price and practice of the manufacturer. But as potaſh alone will not make a ſtiff ſoap, recourſe is

[e] Encycl. Meth.

had to the action of common falt, which, when added after the potafh and oil are united, produces a feparation of the compound from the water incorporated with it, hardens it, and renders it equal to the foda foaps.

The following is the ufual method of making the common white and yellow foap ufed in domeftic purpofes.[f]

White hard foap is generally made with three feparate charges of ley. The potafh (fuppofing this to be the alkali) is previoufly diffolved with water in a fmall boiler with a little fire, and the folution is poured over a vat containing common wood-afhes mixed with lime, which makes the firft and ftrongeft ley.

As foon as this has run off the afhes are turned, more lime is added, and water is pumped on, which forms the fecond or weak ley. The large boiler is then charged with the tallow, and about two-thirds of the ftrong ley being added, a moderate fire is kept up to incorporate the materials, which is known by their running into a ftiff glue. If this does not take place in about 7 hours (with 29 cwt. of tallow in the boiler) more alkali muft be added. The tallow is then *killed* or faturated, and the fire is drawn and the materials allowed to remain at reft for a fhort time. Common falt is then thrown in, and ftirred up with long poles till it is thoroughly incorporated, and till the matter changes from a dark coloured glue to a thin foapy fubftance. A brisk fire is then made, and the materials boiled for a few minutes, when the fire is again drawn, and the materials in the boiler allowed to fettle for an hour and a half, during which the fpent lees fink to the bottom of the boiler, and are pumped off. The fecond operation begins with raifing the fire and adding to the foapy mafs the weak ley, which is to be managed the fame as at firft and again brings it to the ftate of a glue, which a very little falt will reftore to the faponaceous ftate, and after boiling and cooling the fecond lees are pumped off. In the third operation the third part of the ftrong ley which was referved is added, which as before, changes the mafs to a thick glue, that muft be grained with falt as before.

The contents are then boiled ftrongly for three hours, more or lefs, till by taking famples occafionally with a trowel, the foap feels fufficiently hard and dry to the touch, and the ley will be feen to run quite clear from the foap on the trowel, leaving this latter in round lumps. The boil of foap is then finifhed by pumping off the fpent ley, and fcraping off a quantity of light froth from the top of the foap. The foap is then fit for framing, which is a perfectly fimple procefs, and has already been defcribed.

With regard to the proportion of ingredients, it is reckoned that 16 bufhels of good wood-afhes are equal in alkali to 1 cwt. of the beft pearl-afh, and that this latter quantity will faturate 2 cwt. of tallow, and produce 3 cwt. 1 qr. of foap, fo that 12 parts of tallow will make 20 of foap. Alfo, 12 bufhels of wood-afhes are reckoned equal to 1 cwt. of barilla, and the latter quantity will faturate 1½ cwt. of tallow. A boil of 29 cwt. of tallow with 10 cwt. of barilla, and 5 cwt. of pearlafh (as thefe alkalies are often mixed) requires about 8 cwt. of common falt.

Common falt appears to have two diftinct ufes in foap-making; one is, that of promoting the *graining* or feparation of the foap from the fpent ley, which it does probably fimply by abftracting the watery part. In this way it is of as much ufe in the foda as the potafh foaps, and in each it confiderably haftens the procefs; but it is by no means effential, and on account of its high price appears to be feldom ufed, where barilla or foda is the fole alkali. But where a large portion of the alkali is potafh, the foap would remain in the ftate of a foft pafty mafs (as we have already feen) and actually does fo, till the addition of common falt, which then brings the foap to the fame ftate as the foda foaps.

It is therefore probable, as fuggefted by Pelletier, that in thefe cafes a double decompofition takes place between the oil and potafh on the one hand, and the muriatic acid and foda on the other, and that the products of this change of principles are a foap with oil and foda, and muriat of potafh in the mother liquor.

To illuftrate this, the fame ingenious chemift made the following experiments: 3 lbs. of olive oil were boiled with a potafh ley following the fame precife procefs as that already defcribed for the foda foap with this oil, and the refult was a foft foap of the confiftence of butter weighing 8 lbs. On the other hand 6 lbs. of common falt were diffolved in fufficient water and this folution was added by degrees to the foft foap again made fluid by boiling. After keeping up the fire for two hours, the whole was cooled, and a very folid foap collected at the furface which was again melted

[f] Original Communication.

with water to wash out the adhering salt, and then framed in the usual manner. After two months it weighed only 5 lbs. and was hard, white, and of an agreeable smell. The same experiment was repeated with similar results, employing the sulphat of soda instead of the muriat.

It is rather singular however that this accurate chemist did not (as appears) examine the spent ley to discover in it the potash, which he supposes to be displaced from the first soap, but the experiment may easily be made. A similar trial was also made with 3 lbs. of suet and potash, which after the addition of common salt, gave a hard soap, weighing, in two months time, about 6 lbs.

The common yellow soaps are made in this country with tallow and barilla, to which, after saponification, is added a quantity of rosin, and sometimes a very little palm-oil.

The tallow is first compleatly saturated with the ley till the clear liquor, which is drawn off after due boiling, is nearly as alkaline as when added, after which the rosin is melted in, and thoroughly incorporated.

The following gives a good yellow soap, viz. 25 *cwt.* of tallow, 4½ *cwt.* of oil, 7 *cwt.* of rosin, 18 *cwt.* of barilla; and 10 *cwt.* of black ashes (or waste ley evaporated and calcined) and ½ *cwt.* of palm oil. The produce is about 64 *cwt.* of yellow soap.

In the preparation of all the hard soaps, a separation of the soap from the watery saline solution always takes place towards the end of the process, and it is this separation which enables the artist to collect and dry the soap. But the question occurs, how this separation takes place; for the liquor from which it separates is still alkaline, often very strongly so, and if the same soap, after it is fully prepared and dry, is redissolved in an alkaline liquor, it will mix with it uniformly into a white saponaceous fluid.

Pelletier[g] has endeavoured to shew by some ingenious reasoning, and by experiment, that carbonic acid is an essential ingredient in the hard soaps, and from the fact that caustic alkali will decompose alcohol, and become more or less carbonated by the carbonic acid, which is thereby generated, (*for which see the article Potash*) he infers that during soap-boiling, the pure alkali and oil first unite into a saponaceous mass, during which he supposes that part of the oil is decomposed, and furnishes carbonic acid, which then unites with the saponaceous fluid, and forms with it a triple compound of oil, alkali, and carbonic acid, which constitutes hard soap. In the preparation of soap without heat he further supposes that part, if not all, of the carbonic acid may be furnished by the atmosphere, which will account for the length of time required before the soap made in this way will harden and separate from the ley.

He also gives the following experiments: Four ounces of caustic soda ley were mixed, without heat, with eight ounces of oil of almonds, and with frequent stirring, but it was not till after many days, that the soap began to harden. On the other hand 4 oz. of the same ley, 8 oz. of oil, and 4 oz. of water slightly carbonated, were mixed together; the compound soon began to stiffen, in a quarter of an hour it had acquired the consistence of an ointment, and in 12 hours it was hard enough for use. Also 4 oz. of the ley were mixed with 8 oz. of the oil previously aerated with carbonic acid, and here too the soap became solid much sooner than in the first instance, though later than in the second experiment. If it be objected to this opinion of the necessity of carbonic acid to hard soap, that a carbonated alkali will not make soap, the author brings the analogy of calcareous cements or mortar; for sand and carbonat of lime will not cohere into a mortar, but when the combination between sand and quicklime is once made, the induration is much hastened by adding carbonated water.

To this ingenious hypothesis however we may object that there is no proof brought that soap actually contains carbonic acid, and the contrary may be inferred from its not effervescing with a stronger acid, so that the analogy with calcareous mortar is defective in the most essential point. To ascertain the precise action of the alkali on oils, it will also be necessary to examine the spent ley, which appears to contain what alkali remains in it, in a much more carbonated state than the fresh ley; so that instead of supposing that the soap contains carbonic acid, we might with as much probability conjecture that in the process a part of the alkali becomes to a certain degree carbonated at the expence of the other, and that it is the latter portion, or the pure alkali, which unites with the oil into soap, whilst the former separates from it through the assistance of its carbonic acid. This would perhaps explain equally well the action of carbonated water in

[g] Memoirs de Pelletier. tom. I.

hastening the separation of the soap from the remaining ley, but much remains to be done by the scientific chemist in illustrating this very important manufacture.

* * *

The chemical properties of every alkaline soap are the following: when wetted, it swells, softens, and absorbs a large quantity of water, and if more is added it dissolves therein, making a solution which at first is somewhat opalescent or grey but by repose becomes clear. Soap-water when agitated forms a large quantity of white frothy bubbles which remain for a considerable time before they burst, and may be inflated to a vast bulk, as is seen in the common amusement of blowing soap-bubbles. Hot water dissolves soap more rapidly and in larger proportion than cold. Soap will keep in a dry place for a great length of time unaltered, but when damp, a part of the alkali gradually separates and appears on the surface as a saline efflorescence of carbonat of soda. Distilled *per se*, it yields most of its oil tolerably pure, after which the residue blackens, exhales a fetid smell and black smoke, and finally the alkali alone is left in a carbonated state.

Soap is also soluble in alcohol.

The solution of soap is decomposed by all the acids, which *curdle* it, or separate the oil in the form of white lumps. An excess of acid redissolves the curd, and the oil is transferred to the acid, but on boiling this solution, the oil separates entirely, and rises to the surface. The solution is also curdled by lime, barytic or strontian water, and in this case the curd consists of the oil united with the earth and concreted by this union. All the soluble salts of these and the other earthy bases equally decompose soap-water, and form a curdy precipitate, which is the reason why *hard* water, that always contains sulphat of lime, and often other earthy salts, immediately curdles soap instead of forming an uniform solution. The metallic salts also produce the same effect, and a combination of the oil and metallic oxyd is produced.

These several decompositions have been examined by Berthollet.[h] The oleo-calcareous curdy precipitate formed by adding a solution of soap to lime-water, is not altered by caustic alkali, which proves that oil has a stronger affinity with lime than with alkali, but if a carbonated alkali is used, the oleo-calcareous compound is decomposed, the lime becomes carbonated, and separates, and the alkali goes to the oil. This also affords another presumptive argument against the existence of carbonic acid in common soap. Ammonia has no more effect on the oleo-calcareous compound than the fixed alkalies have, but if carbonated ammonia is digested with it, carbonated lime is produced, and the ammonia and oil unite compleatly. If this latter solution is evaporated, a soap remains, which is more pungent than common soap, is largely soluble in alcohol, but imperfectly so in water. A similar ammoniacal soap is formed, and separates immediately in white curds by adding a solution of common soap to muriated ammonia.

It has been mentioned that all the earthy salts decompose soap. With Epsom salt an oleo-magnesian precipitate is formed which is unctuous, dries with difficulty, is insoluble in boiling water, but easily dissolves in alcohol or expressed oil. In a moderate heat it melts into a yellowish transparent mass.

An oleo-aluminous compound is formed by adding alum to a solution of common soap. This forms a soft flexible mass, which preserves its suppleness in drying, and is scarcely soluble in water, alcohol, or oil.

The same excellent chemist examined several of the oleo-metallic compounds formed by adding a solution of soap to the metallic solutions. With corrosive sublimate a quantity of small coagula were produced, and more readily with nitrat of mercury. This combination is viscid, dries with difficulty, dissolves in oil and alcohol. It becomes of a deep slate colour by exposure to the air, and readily softens by heat.

Sulphat of zinc decomposed by soap gave a yellowish white compound; the nitro-muriat one of a dull leaden colour.

Nitro-muriat of tin gave a white compound, which differed from all the others in not being fusible by heat, owing to the quantity of metallic oxyd which it contained.

The salts of iron give a reddish-brown oily compound, very tenacious and easily fusible. It is readily soluble in oil and oil of turpentine.

Sulphat of copper gives a copious green mass resinous in appearance, which becomes brittle on drying. Digested in alcohol its colour deepens, but it does not dissolve except with heat. Ether much improves the colour and dissolves a portion. This compound is readily and largely soluble in oils to which it gives a green colour.

Acetite of lead gives a white tenacious mass, very adhesive when heated, and resembling diachylon, which is a direct combination of oil and litharge.

[h] Mem. de l'Acad. for 1780.

The author adds a few general remarks on these combinations. The expressed oils did not appear to dissolve the compound of oil with lime or alumine. Alcohol dissolves some of the oleo-metallic compounds without heat, others require heating; but in all cases it dissolves less of them than oil of turpentine does.

Some of these were calcined, to determine the quantity of earth or metallic oxyd left after the oil was burnt off, whence some idea may be formed of the proportions of ingredients in these compounds, taking into account however, that the calcination might carbonate some of the earths, but not all, and that the exact state of oxygenation of the metals is not ascertained. Half an ounce, Fr. (288 grs.) of the compound with magnesia left 32 grs. which did not effervesce: the compound with lime left 36 grs. which effervesced; with clay, 28 grs; with iron, 48 grs; with copper, 33 grs; with zinc, 42; with manganese, 40; with silver, 30 grs. in the metallic state; and with tin, as much as 79 grs. of the reduced metal. Whenever these combinations are to be made, the solutions should be in a saturated state.

Ammoniacal Soap.

A white saponaceous compound is readily made by shaking any oil with liquid ammonia, and this combination is much used medicinally as a stimulating application; but the union between the two is much weaker than between the fixed alkalies and oils, so that this compound will not harden, and by keeping for a time the ingredients partly separate. A more intimate union between them is made by adding muriated ammonia to common soap, as has been already mentioned.

Essential-Oil Soaps. Starkey's Soap.

The combination of the essential oils with the fixed alkalies is much more difficult than that of the expressed oils and fats, and much less perfect, so that a separation is liable to take place whatever pains be taken in the mixture. This kind of soap was first introduced by an alchemist of the name of *Starkey*, whence it has taken its name. Starkey's process was tedious and uncertain. It consisted in putting in a vessel some dry carbonat of potash with oil of turpentine and shaking the mixture daily for six months, during which time part of the oil combines with the alkali into a saponaceous mass, and the remainder floats above it unaltered. Beaumè has taken a good deal of pains to find out the best method of making this mixture. His method is the following.[1] Put in a marble mortar, or on a porphyry stone, any quantity of dry carbonat of potash, add to it gradually twice or thrice its weight of oil of turpentine, and rub them together till the mixture has the consistence of a soft extract; then put it into a glass cucurbit and set it (at rest) in a damp place, during which the mixture absorbs much moisture from the air, and resolves itself into three portions, the lowest of which is a watery solution of the alkali, the middle is the soap required, and the upper portion is some uncombined oil of turpentine, generally yellow or amber-coloured. Pour the whole on a strainer of double cloth, and the soap alone remains on the strainer, which after draining for some days must be again rubbed in a mortar, and is then compleat. The alkaline liquor that runs through the filter is somewhat impregnated with the oil. Other recipes have been given for this soap, the preparation of which has engaged more attention, perhaps, than it merits as a medicine, and which need not be repeated in this place. This soap has an acrid alkaline taste, and is very apt to deliquiate on exposure to air.

It does not appear however that the solid caustic alkalies have ever been used for this purpose, so that experiments are still wanting to ascertain the precise action of the alkalies on the essential oils.

Acid Soaps.

The combination of acids with oils into soluble saponaceous substances, has already been noticed under the article OIL.

SOAP, *Starkey's*. See the preceding article.

SOAP-LEES. *Lixivium saponarium.*

This term has been not unfrequently used both by chemical writers, and also familiarly, to signify the *ley* or alkaline lixivium used by soap-boilers. In this country therefore it means a very strong solution of potash, nearly, if not entirely caustic; but in the countries where soda is chiefly used by the soap makers, it signifies a ley of caustic soda. It is therefore an incorrect term, and is nearly disused.

The term *soap-lees* is also employed technically by some to signify the *spent ley* which is pumped out of the soap cistern after the soap has separated, and being generally more or less alkaline, it is never thrown away, but is sometimes used again in the state in which it is obtained, and at other times is evaporated and the residue calcined to extract the alkali.

SODA. Mineral fixed Alkali. *Soude*, Fr. *Mineralische gewachsalkali*, Germ.

This alkali is obtained pure from the native

[1] Elemens de Pharmacie.

or unmanufactured CARBONAT OF SODA by precisely the same methods which have been already amply detailed in the article POTASH, to which we refer our readers. In its general properties it so closely resembles potash that it is with the utmost difficulty that the two alkalies when in a pure uncombined state, are distinguished from each other. To avoid useless repetition therefore, we shall only mention here those circumstances in which soda differs from potash. The affinity of soda for water is much inferior to that which potash exhibits for the same substance, hence when solid caustic soda is exposed to the air it presently moulders to a moist paste, but as soon as it has absorbed carbonic acid enough to form the sub-carbonat of soda, it parts again with its water and effloresces to a white powder. Potash on the other hand, entirely deliquiates, and continues fluid till quite saturated with carbonic acid. The specific gravity of soda according to Hassenfratz is $=1.33$, whereas that of potash amounts to 1.70. Soda combines with silex and other vitrifiable ingredients into a glass in the same manner as potash does, but the glass prepared with the latter is harder than when the former is made use of. On the other hand the soaps produced by combining soda with oil or tallow are hard and solid, while those made with potash are soft and gelatinous. The two alkalies are still more distinguishable when united to the different acids, producing compound salts, and a considerably smaller proportion of soda than of potash will saturate a given quantity of acid. The salts with a base of soda are for the most part considerably more soluble than the corresponding ones with a base of potash, and in the force of its chemical affinity soda appears to be somewhat inferior to potash, this however is no doubt increased by the superior solubility of its salts.

Soda is applied in general to the same use as potash, and the preference given to either over the other is often determined merely by their relative commercial value. In the preparation of hard soap and the softer kinds of glass there is however an intrinsic ground of preference.

SOLDER.

The art of soldering is that of joining together two or more pieces of metal by means of a metallic cement: hence it is absolutely requisite that the solder employed should have the two following qualities, viz. that of being fusible at a lower heat than the metals which it is intended to cement, and of adhering with considerable firmness to their surfaces. The solder for gold is composed of fine gold with $\frac{1}{4}$ or $\frac{1}{2}$ its weight of fine silver, mixed together accurately by fusion, and afterwards beat out into leaves somewhat thinner than card paper, and rendered as soft as possible by annealing. It is made use of in the following manner. A piece of solder of the proper size and shape being cut off, is laid on the part to be cemented and sprinkled over with pulverized borax; the flame from a blowpipe is then applied, and the borax and solder both enter into fusion, the latter incorporating with and adhering firmly to the gold: when the juncture is compleat the piece is allowed to cool, and the borax is removed by boiling water, or what is still better a little dilute sulphuric or muriatic acid. The solder will however appear considerably paler than the other part, both on account of the silver with which it is alloyed, and of the borax, which always lowers the colour of gold: this defect may be remedied by melting on the surface of the solder a mixture of two parts of nitre and one of burnt alum and afterwards washing it off with a soft brush and hot water, by which the natural colour of the gold will be restored and even heightened.

For silver there are two kinds of solder employed, the hard and the soft. The former is composed of equal parts of silver and fine brass; and the latter is prepared by fusing the hard solder with $\frac{1}{16}$ of its weight of pure zinc. The mode of applying it is the same as already directed for gold solder.

For copper, brass, and the hard alloys of copper the best hard solder is composed of brass and zinc in the proportion of from 8 to 16 of the former to one of the latter, according to the required hardness. The soft solder is composed of 3 parts of zinc and one of lead, and is applied by means of a common soldering iron heated red hot.

The solder for tin, pewter, and lead, (or the plumber's solder) is of two kinds: the least fusible is composed of equal parts of tin and lead; the more fusible contains besides, bismuth in various proportions. A very good soft solder is prepared by melting together 16 parts of tin, 8 of lead, and 4 of bismuth.

For delicate works in cut steel the best solder is gold with a high alloy of copper. For larger works in iron and steel copper is made use of, or an alloy composed of equal parts of tin and iron.

SOLUBLE TARTAR, or *Tartrite of Potash*. See TARTAREOUS ACID.

SOLUTION. *Auflosung*. Germ.

Solution is the perfect chemical union of a solid or fluid with any other fluid, in which the compound remains in a liquid state, and perfectly homogenous in all its parts. It generally is applied to the *melting down* of a solid in a fluid (salt in water for example) but applies with equal propriety to the chemical union of two dissimilar fluids, as where an essential oil is dissolved in alcohol.

Solution is one of the great operations in chemistry, and almost every substance in nature is capable of it. The antient idea of solution does not imply chemical affinity, and the substance dissolved was supposed to be as it were passive in the operation, so that in this point of view, solution was little else than *transparent diffusion*. But more accurate ideas of chemical action have shewn that solution takes place from true chemical affinity operating between the *solvent* and the *solvend*, in which each substance equally participates. For a solid to be dissolved in a fluid it is necessary that the force of affinity between the two should be sufficient to overcome the force of cohesion between the particles of the solid, and hence it is that heat so much assists solution by lessening the force of cohesion between all particles of matter.

It generally happens in all cases of solution at a common temperature that the mixture in the act of solution becomes either warmer or colder than the ingredients were before mixture. This arises from an evolution or absorption of free caloric, owing to the mixture having a less or a greater capacity for caloric than the mean capacity of the two substances taken separately. This has been more fully explained under the article *Caloric*.

It happens also in by far the greater number of cases of solution that the mixture has a greater specific gravity than the mean gravity of the ingredients, relatively to their respective quantities. Hence they occupy less space than before, as may readily be seen by putting into a bottle any soluble salt (sulphat of soda for example) and filling it brim-full of water, and after the solution is effected, the liquor will have sunk a certain way below the first level without any loss of the ingredients.

The whole subject of solution is intimately connected with that of chemical *affinity* to which we shall refer the reader.

SOOT.

Chimney soot is a compound of black carbonaceous matter with a considerable quantity of carbonated ammonia and probably some other ammoniacal salts, and hence it gives a strong pungent smell of this alkali when rubbed with quicklime. Carbonated ammonia is extracted from it in the large way in several manufactories of this salt.

SORREL, *Salt of*, is the native super-oxalat of potash contained in the juice of this plant. See OXALIC ACID.

SPANISH WHITE.

The substance originally called by this name, is the white of oxyd or magistery of bismuth, the name is often however applied to washed chalk or *whiting*.

SPAR. *Spath*. Germ.

The term spar, in its most comprehensive sense appears to include almost all the earthy crystallized minerals that are met with in metallic veins; but by mineralogists it is applied to those minerals whether earthy or metallic, which are crystallized and have a visible foliated texture. Thus we say calcareous spar, fluor spar, heavy spar, felspar, lead spar, spathose iron, &c. but not quartz spar. It is not however every foliated crystal which is called a spar, for neither mica nor hornblende bear this appellation. The adjective spathose or sparry, means composed of *crystalline* plates, in opposition to foliated or slaty, which only imply composed of plates, without any reference to crystallization.

SPARGELSTEIN. See APATIT.

SPECKSTEIN. See STEATITE.

SPECULUM METAL. See COPPER, alloys of.

SPELTER.

Is the usual commercial name for ZINC.

SPERMACETI. *Blanc de Baleine*. Fr. *Wallrath*. Germ.

This peculiar oily substance is found abundantly in the cranium of the cachalot or spermaceti whale (Physeter macrocephalus, *Linn.*) and in some other species of the same genus: but though contained in the cavities of the scull it appears to be entirely different from the proper brain of the animal. When first extracted it is mixed with a considerable quantity of oil, which is separated by putting the mass into a woollen bag and pressing it, by which the greatest part of the oil runs out, and then washing the residue with a warm weak alkaline ley, which dissolves and converts into soap the remainder of the oil, leaving behind the spermaceti untouched; this latter after being repeatedly washed with soft water, is melted by a very gentle heat, the impurities partly float on

the furface, and partly fink to the bottom; and are thus got rid of; the fluid, in appearance a perfectly pellucid oil, is now allowed to cool, and forms on congealing a mafs of purified fpermaceti.

The colour of fpermaceti is a pure brilliant almoft filvery white; it is compofed of femi-tranfparent cryftalline plates; is fofter and more brittle than white wax, has very little flavour, and only a flight tallowy odour. Its fuperior tranfparency, high luftre, and cryftalline texture, at once diftinguifh it from every other fpecies of concrete oil. Its point of congelation is 112° Fahr. By the affiftance of a wick it burns with a clear white flame, fuperior to that of tallow, and without any difagreeable odour, hence its excellence as a material for candles.

Spermaceti by diftillation at a gentle heat, paffes over in the ftate of a fluid oil, which concretes on cooling, a very flight carbonaceous refidue being left in the retort; by repeated diftillation, however, the fpermaceti becomes permanently fluid at the common temperature. It requires according to Thouvenel, a much lefs heat for its volatilization than moft of the other oils do, and therefore is lefs decompofed by the procefs; in particular no acid makes its appearance. But according to the experiments of Crell a greater heat is required for its diftillation than for that of fat, the coagulated oil, thus procured, is partly white and partly brownifh; by repeated diftillation it affords a yellowifh acid, becomes more fluid, but ftill coagulates in the cold. The acid when rectified by diftillation is entirely colourlefs, and affords the fame falts with earths and alkalies as Crell's febacic acid. The oil unites with ammonia into a faponaceous emulfion.

Spermaceti is foluble in boiling alcohol, though very fparingly, 150 parts of the menftruum being required for this purpofe, and the whole of the fpermaceti appears to be again precipitated as the folution cools.[a] Warm ether diffolves it very copioufly, but feems to retain none of it when cold. Oil of turpentine has the fame effect. With cauftic potafh it combines into a foap, foluble in warm water. Fluid ammonia when cold has no action on fpermaceti, but when warm diffolves it with great facility, forming an emulfion which is not decompofed either by fimple cooling, or by mixture with water; the addition of an acid however inftantly precipitates the fpermaceti. With concentrated fulphuric acid it forms a brownifh folution, which when dropped into water gives up its fpermaceti apparently unaltered. It diffolves fulphur as the other fat oils do. By long expofure to the air it acquires a yellow tinge and becomes rancid.

The great ufe of fpermaceti is for making candles; it is alfo employed in medicine.

SPINELL, or true Ruby. *Spinell*, Wern. *Spinelle*, Hauy and Broch.

Its colour is red mixed with various tints of blue or yellow; hence it occurs carmine, hyacinth, cochineal, and cherry red, rofe red, and rarely blood red, alfo violet blue, bluifh green, and orange yellow. It occurs in grains, in fmall rounded fragments, and cryftallized.

The primitive form of its cryftals is the regular octohedron, befides which it exhibits the following varieties.

1. The cuneiform octohedron.

2. The primitive octohedron with the edges of the common bafe truncated.

3. The fame with all the edges truncated.

4. The primitive octohedron divided obliquely into two fegments which are turned on each other ¼ of a circle, thus forming a folid with alternate faliant and re-entering angles.

The cryftals are fmall and very fmall, rarely middle-fized. The faces of the octohedron are fmooth, the planes of the truncatures are longitudinally ftriated. Its luftre both externally and internally is brightly fhining, vitreous. Its crofs fracture is conchoidal, its longitudinal fracture is lamellar in three directions. It varies from tranflucent to tranfparent. Its hardnefs is very confiderable, though inferior to that of fapphire. Sp. gr. 3.57—3.64.

It is infufible before the blowpipe without addition, but it melts with borax and acquires a green colour. When ground to a very fine powder, it is foluble by long digeftion in boiling fulphuric acid. It was firft analyfed by Klaproth, and afterwards by Vauquelin, with the following refults.

Klapr.		Vauq.	
74.5	—	82.47	Alumine
15.5	—	0.	Silex
8.25	—	8.78	Magnefia
1.5	—	0.	Oxyd of iron
0.75	—	9.	Lime
0.	—	6.18	Chromic acid
100.50	—	97.43	

Its geological fituation is not known; it occurs however imbedded in calcareous fpar and

[a] Boftock in Nich. Journ. 8vo. iv. p. 34.

adularia, accompanied by mica and magnetic pyrites. It is found in Pegu and the island of Ceylon.

Spinelle ranks among the gems; and is called by different names among the jewellers, according to the tone of its colour. The pure bright red is called *Spinelle*, and is the most esteemed, its value when exceeding 4 carats in weight, being half that of a diamond of equal weight; the orange red variety is called *Vermeille*, or *Rubicelle*; and the rose red is called *Balais* or *Balass* ruby. The oriental ruby is a variety of Telesia.

SPINTHERE.

The colour of this mineral is greenish. It occurs crystallized in irregular dodecahedrons, composed of a double four-sided pyramid, obliquely truncated at the apexes. The crystals are very small and brightly shining; the fracture is lamellar. Its hardness is inferior to that of glass; it is translucent on the edges.

It melts before the blowpipe without much difficulty. It has not been analysed.

It was discovered by Hauy implanted in calcareous spar from Dauphiné.

SPIRITS DISTILLED.

Under the articles *Fermentation*, *Brandy*, and *Alcohol*, we have already given a description of the processes by which ardent spirit is made, and of its chemical properties; we shall therefore in this place only mention a few circumstances in the preparation of *corn-spirits* and *rum*.

The greater part of the common spirituous liquors consumed in this and other countries of Europe where the vine does not grow, is prepared from fermented corn of one kind or other, mixed occasionally when it suits the purpose of the distiller with molasses, and sometimes with carrots and other sub-saccharine vegetables. But when there is no scarcity of grain, this is by far the greatest, and often the only ingredient.

The spirit thus procured is rectified for sale by being re-distilled with juniper-berries, turpentine, and many other substances to give it the desired flavour and appearance.

The grain, if barley is used, is generally first malted in the usual manner, and in Scotland is dried with peat, the smoke of which gives that peculiar flavour which is found in *whisky*, the spirit distilled from it. It is then ground to coarse powder, mashed, and the infusion fermented with yeast in large tuns. In this state it is a strong ale, and differs from the malt-liquors used for drinking, only in containing no hops nor any other bitter. This fermented liquor is called *wash*, and is then fit for the first distillation.

The theory and practice of distillation having been described under the articles *Alcohol* and *Brandy*, we shall not here repeat it, except to mention that several additions are made to the wash with a view either of increasing (as is supposed) the yield of spirit, or of correcting and keeping down the essential oil derived from the malt which is apt to give it a nauseous flavour; or of regulating the boiling within the still, and preventing it from boiling over or *running foul*; or of neutralizing the acid generated during the fermentation, which remarkably lessens the product of spirit. For all these purposes soap is accounted the best addition, and large quantities of it are employed for this purpose in distilleries. Others use alkalies.

During the distillation the first spirit that comes over (as in the distillation of wine) is oily and turbid, and often of a nauseous flavour, owing to the oil of the malt which accompanies it in all these changes. The spirit then runs clear and continues so to the last, but constantly decreasing in strength, becoming more watery, and therefore of less specific gravity.

The whole of the spirit thus obtained is then again distilled or *rectified*, and in this process the middle runnings from the still are received apart from the first portion which is too oily and turbid, and from the latter which is too watery to come up to the established proof. It is in the rectification also that the additions which give a peculiar flavour to the spirit, (such as juniper berries, &c.) are made.

The general process of the distillery is simple, and certainly not difficult of management to ensure a certain degree of success, since it is carried on in the small way by hundreds of small farmers and ignorant persons in those remote parts of the island which offer the greatest facility of eluding the excise duties. But in conducting vast and expensive works a large share of practical skill is required, and almost every distiller professes to have some peculiar nicety of practice in the management of the process or the construction of the apparatus.

The form of the still in particular has undergone many successive alterations (especially in Scotland, where the mode of levying the duty renders it an object to distill as fast as possible) and by gradually widening the bottom and contracting the height of the boiler, distillation

is now carried on with a rapidity that would almost exceed belief were it not perfectly well authenticated.[a] After successive improvements and a considerably complicated apparatus, a still has been constructed which contains only 40 gallons in the body and 3 in the head, in which the time of charging, boiling and running, and letting off the waste liquor, amounts only to *two minutes and three-quarters* when the charge of wash is 16 gallons, which is two-fifths of the whole contents. In rectification, which is a slower process, the charge is 24 gallons, and the time of distilling about ten minutes. This rate of working however is far beyond the ordinary rate.

It is not necessary to malt grain in order to make it ferment sufficiently to yield a good spirit, and not only barley but any other grain will answer the same purpose. In this country a mixture of barley and malt is generally preferred; in Holland the very finest geneva is made from wheat and malt, but more commonly from malt and rye, which latter yields more spirit than wheat. Very superior care and attention seems to be bestowed in conducting the whole process.

The greater number of distillers proceed in the following manner.[b] A quantity of rye-flour coarsely ground is mixed with a third or fourth part of malt and put into the fermenting tub with cold water, stirring it well with the hands to prevent the meal from clotting. Sufficient water is then added of a blood warmth, after which the ferment is mixed with the whole, which is composed of the yeast of former operations dried and kept for a certain time. If the weather is favourable and the heat well regulated, the fermentation begins in six hours, and terminates on the third day, and the liquor becomes transparent and assumes a hot pungent taste. The distillation is then proceeded upon immediately, before the liquor turns sour, which is avoided as much as possible. The distillation is conducted very slowly, that the spirit may be as little as possible impregnated with the oil of the grain, to which much of the unpleasant flavour of the ordinary spirits is justly attributed. The first spirit is then rectified by a second distillation over juniper-berries, or in *double Geneva* by a third process. In some of the ordinary sorts however the juniper-berries are mixed with the fermenting materials, and one distillation suffices. In the common geneva or gin vulgarly used in this country, the fine juniper flavour is coarsely imitated by turpentine.

Rum is prepared by distilling a fermented liquor made from melasses, and other refuse saccharine matter which is procured during the manufacture of raw sugar in the West Indies. The common process in Jamaica is the following.[c] The materials for the fermentation are, molasses or the treacle which drains from the sugar, scummings of the hot cane juice, or sometimes raw cane liquor, lees or *dunder* as it is called, and water. The dunder answers the purpose of yeast, and is usually prepared by a separate fermentation of cane sweets and water. The materials being mixed in due proportions, (which are about equal parts of scummings, dunder, and water) the fermentation begins very soon, and in 24 hours the liquor is fit for the first charge of melasses, which is added in the proportion of 3 gallons for every 100 gallons of the liquor. Another charge is added in a day or two afterwards. The heat in fermentation should not exceed 90° or 94°, so that in this climate it is necessary to keep the fermenting tubs as cool as possible. The fermentation falls in six or eight days, and the liquor grows fine and fit for distillation. In about two hours after lighting the fire the spirit begins to run (in a still of 1200 gallons) and it is collected as long as it remains inflammable.

The first spirit is called in the country, *low wines*, and it is rectified in a smaller still to the Jamaica proof, which is that in which olive oil will sink. About 220 gallons of proof rum are obtained from 530 gallons of low wines.

SPIRIT OF LIBAVIUS. See TIN.

SPIRIT OF MINDERERUS. See ACETITE *of Ammonia*.

SPIRIT OF NITRE. See NITRIC ACID.

SPIRIT OF SALT. See MURIATIC ACID.

SPIRIT OF SULPHUR, OR OF VITRIOL. See SULPHURIC ACID.

SPIRIT OF TURPENTINE. See TURPENTINE.

SPIRIT OF WINE. See ALCOHOL.

SPIRITUS RECTOR. See AROMA.

SPONGE.

This substance was examined by Mr. Hatchett in his series of valuable experiments on the component parts of animal membrane.[a] When sponge has been immersed in dilute nitric acid for a fortnight, the acid becomes pale yellow and is changed to an orange by pure

[a] Report to the House of Commons on the Distilleries in Scotland, Dr. Jeffray's Memoir. [b] Ibid. Mr. Crookeen's Mem. [c] Edwards's History of the West Indies. [a] Phil. Trans. for 1800, p. 352.

ammonia. The ſponge after this proceſs becomes more or leſs tranſparent, and conſiderably ſoftened, and is then compleatly ſoluble in ammonia into a deep orange-coloured liquor. When digeſted with boiling diſtilled water, ſponge gives out a portion of gelatin, which is precipitated by infuſion of oak-bark. The ſponge by loſing its gelatin, becomes much leſs flexible than before, and is eaſily torn when moiſt, or crumbles between the fingers when dry. When ſponge either in its natural ſtate, or eſpecially when its gelatin has been extracted by long boiling with water, is boiled with cauſtic potaſh, it compleatly diſſolves therein and forms an animal ſoap.

Sponge, when heated in a cloſe veſſel, gives out an ammoniacal fetid ſmoke, and is reduced to a black charcoal, which, after incineration, leaves a ſmall quantity of common ſalt and ſome carbonat of lime.

Charred or burnt ſponge is uſed in medicine.

The chief conſtituent parts of ſponge therefore are, animal gelatin, and that condenſed albumen which Mr. Hatchett has found to be the principal part of all ſoft membranous organs, of cartilage, &c. The former is diſſolved, though with ſome difficulty, in boiling water, but does not yield to cold water; the albumen is inſoluble in water at any temperature, but yields to cauſtic alkali.

STAHL's SULPHUREOUS SALT. See SULPHITE of *Potaſh*.

STANGENSPATH. See HEAVY SPAR.

STALACTITE } See LIMESTONE.
STALAGMITE }

STARCH. Amidon, *Fr.* Starkmehl, *Germ.*

Under the article *Fecula*, the chemical properties of the ſtarch, or fecula of all vegetables, have been deſcribed; we have therefore only in this place to mention ſhortly the mode of manufacturing the common ſtarch which is made, for ſale, almoſt excluſively from wheat. This grain conſiſts of gluten, fecula, a colouring extractive matter, and phoſphat of lime, and it is the object of the ſtarch-maker, to ſeparate the fecula alone from all the other ingredients. This might be done, one would think, ſimply by grinding the wheat into very fine flour, mixing the flour with water into a ſtiff paſte with much beating, and then expoſing this paſte with uninterrupted agitation to a gentle current of pure water, which would run off milky with the ſtarch as long as any of it remained in the paſte, and the gluten alone would be left behind. This milky water would depoſit the ſtarch by remaining at reſt for a time.

A ſimilar method is followed in the ſmall way in making potatoe ſtarch, as mentioned under the article *fecula*, only with leſs labour, as this contains no gluten.

Wheat ſtarch is not made however exactly in this ſimple way, but the grain after being coarſely ground, is ſuffered to ferment or mould with water for many days, by which its texture is entirely broken down, and the ſtarch which is ſcarcely alterable in the proceſs, is probably more effectually ſeparated from all the other ingredients, and obtained finer and whiter. The actual method is (in a few words) the following:[*] The wheat is firſt coarſely bruiſed, and placed in large wooden vats or reſervoirs, watertight, and intimately mixed with water. Here a fermentation begins after a time, which is a mixture of the vinous and acetous, and is attended with a ſtrong, unpleaſant, ſour, mouldy ſmell. The wheat remains in the vat for about a fortnight, till the fermentation ceaſes, which is known by its ſettling at the bottom of the vat. The contents are then emptied ſucceſſively into a ſmall tub, and mixed with freſh water, till all the pulpy part is thin enough to paſs through a hair ſieve, which ſeparates the bran from it. What has gone through contains the ſtarch ſuſpended in a very ſour water, and conſiderably foul. This is put into tubs or frames, and allowed to remain for two days undiſturbed, during which the impure ſtarch ſettles to the bottom. The water is then drawn off, the frames turned on their ſides, and the dirty diſcoloured part of the ſtarch (which is the laſt that ſubſides and therefore is at the top) is ſcraped off, and the remaining ſtarch is well waſhed and bruſhed, till it is nearly free from this muddy ſediment, which is called *ſlimes*, and is treated ſeparately to obtain its ſtarch. The ſtarch is ſtirred with freſh water, and ſuffered to ſettle, and again cleanſed, till all its impurities are removed, and is then mixed with water enough to make it liquid, and paſſed through a fine lawn ſieve. It is then fit to receive its colour, which conſiſts of ſmalt mixed with water and a ſmall quantity of alum, and is thoroughly incorporated with the ſtarch. After again ſettling, the ſtarch is taken out and put into oblong boxes, about ſix feet long and one broad, with holes at the bottom, and lined with linen cloth, where the moiſture of the ſtarch drains off till it becomes ſolid enough to be cut into ſquare lumps. Theſe are

[*] Original Communication.

laid on new bricks which abſorb much of their moiſture, and make them hard enough to be ſtoved. Here the ſtarch remains in a moderate heat, till a ſlimy cruſt riſes to the ſurface, which is carefully ſcraped off, and the reſt, which is now perfectly pure ſtarch, is papered and placed again in the ſtove with a good hot fire, till quite dry. This laſt ſtoving cauſes the lumps to crack pretty uniformly into the ſmall pieces in which they appear when ſold. The *ſlimes* are all treated in the ſame way till all the ſtarch is got from them. All the refuſe matter from ſtarch making makes very valuable food for fattening hogs. The whole time of making ſtarch, from the firſt ſteeping of the wheat to the laſt ſtoving, is about ſix weeks; and 551 Wincheſter buſhels of wheat will make about ſix ton of ſtarch. This will be about $\frac{7}{17}$ of the entire weight of the wheat.

In the proceſs of ſtarch-making a great quantity of a ſour nauſeous milky water is obtained, from which the ſtarch ſubſides after it is firſt removed from the fermenting vat. This has been analyzed with great care by Vauquelin, with the following reſults.

This liquor has an acid, and at the ſame time a ſpirituous flavour, it ſtrongly reddens litmus, gives a precipitate with lime-water, which an exceſs of the liquor re-diſſolves. Alcohol added to it gives a white, light, ſoft precipitate. Oxalic acid alſo gives a precipitate, which ſhews that the acid contained in the liquor is not the oxalic.

A quantity of this liquor was diſtilled. The firſt product was ſenſibly ſpirituous, and yielded on rectification a notable quantity of pretty pure alcohol. After this, an acid liquor came over, which gave a ſalt reſembling exactly acetite of lead when ſaturated with litharge, acetite of lime, with lime, and therefore was acetous acid. The reſidue in the retort, after moſt of the liquor had diſtilled off, was reddiſh-brown, had a very ſour taſte mixed with that of burnt bread, and a ſyrupy conſiſtence. It was filtered, and the clear liquor gave with lime-water an abundant precipitate, which an exceſs of the liquor rediſſolved; with cauſtic alkalies a ſimilar precipitate was alſo formed, along with an obvious production of ammonia; and with oxalic acid, oxalat of lime was produced. With the ſolutions of lead a white precipitate fell down, and this latter decompoſed by ſulphuric acid, gave another acid which in every reſpect agreed with the phoſphoric.

The ſtarch-ſours therefore contain, beſides a viſible white matter ſeparable by filtering, a quantity of phoſphat of lime and ammonia, both held in ſolution by the acetous acid which is generated ſo abundantly by the fermentation. A peculiar animal matter is alſo found in this acid liquor, which ſeems to reſemble *gluten*, and therefore which only belongs to that ſtarch which is made from wheat flour.

This liquor therefore contains the five following ſubſtances, viz. acetous acid, ammonia, alcohol, gluten, and phoſphat of lime, but of theſe only the two laſt are natural to the wheat; the others are the products of the fermentation, the ammonia being generated by the decompoſition of part of the gluten, the alcohol by the ſaccharine mucilage which all grain contains, and the acetous acid perhaps from all the other principles. The peculiar office which this acid performs in ſtarch-making is to diſſolve the gluten and phoſphat of lime, and thus to ſeparate them from the pure ſtarch. Hence when wheat is the grain employed, ariſes the neceſſity of continuing the fermentation long enough to generate a ſufficient quantity of acetous acid; for the other grains and roots which yield ſtarch contain little or no gluten. A conſiderable quantity however of the ſtarch muſt be deſtroyed in the proceſs, for wheat contains much more of it than is obtained in manufacture, as may be found by waſhing flour paſte with water in the way mentioned in the beginning of this article.

STAUROLITE. Granatite, *Sauſſure* and *Wern.* Staurotide, *Hauy*.

Its colour is reddiſh or blackiſh-brown. It occurs always cryſtallized. The form of its cryſtals is a hexahedral priſm, of which four faces are by much the largeſt and meet in pairs, forming two obtuſe oppoſite angles, meaſuring 129°. This priſm is either entire or truncated on the obtuſe angles. It is not uncommon to find two cryſtals penetrating each other obliquely or at right angles, ſo as to form a croſs; ſometimes even three priſms are thus arranged, forming a triple croſs. Its ſurface is ſmooth or uneven, and its luſtre varies accordingly. Internally it is more or leſs ſhining, with a luſtre between vitreous and reſinous. Its fracture parellel to the axis is imperfectly lamellar: in the oppoſite direction it is ſmall-grained uneven, paſſing to conchoidal. It is brittle, and ſomewhat harder than quartz. Sp. gr. 3.28.

When expoſed to the blowpipe it undergoes no other change than that of fritting a little on its ſurface. Its component parts according to an analyſis by Vauquelin, are

33.	Silex
44.	Alumine
3.84	Lime
13.	Oxyd of iron
1.	Oxyd of manganese
94.84	
Loss 5.16	
100	

It is found in St. Gothard in Switzerland, in small crystals imbedded in micaceous schistus, and accompanied with cyanite; in Brittany near Quimper, in middling sized crystals, imbedded in a micaceous clay, apparently produced by the decomposition of some primitive rock: also at Sant Jago of Compostella, in a primitive rock.

STAUROTIDE. See the preceding article.

STEATITE. Speckstein, *Wern.* Soapstone, Spanish Chalk, Craie de Briançon.

Its colour is greyish, greenish, yellowish, or reddish-white, also flesh-red, mountain-green, and olive-green: the whitish varieties generally contain black dendritical figures and spots. It occurs in mass, disseminated, investing and crystallized. The forms of its crystals are a six-sided prism, terminated by six-sided pyramids; also a rectangular and rhomboidal four-sided prism; also a double six-sided pyramid. It is probable however that several if not all of these are pseudomorphous. The crystals are small and middlesized, generally imbedded in the massive kind, and are very rare. Internally it is dull, or at most faintly glimmering. Its fracture is coarse splintery, rarely earthy, and sometimes intermediate between coarse fibrous and foliated. It is translucent on the edges, rarely translucent. It is soft and very soft, gives a shining streak, may be cut with a knife, is not very frangible, is very unctuous to the touch like soap. Sp. gr. 2.64. Before the blowpipe it becomes hard and generally loses its colour, but is not fusible without addition.

The steatite of Bareuth, according to the analyses of Klaproth and Wiegleb, consists of the following ingredients.

Klap.		Weigl.	
59.5	—	58.33	Silex
30.5	—	39.16	Magnesia
2.5	—	2.5	Oxyd of iron
5.5	—	0.	Water
98.0		99.89	

The steatite of Cornwall, according to Klaproth, consists of

48	Silex
20.5	Magnesia
14.	Alumine
1.	Oxyd of iron
15.5	Water
99.0	

It occurs in beds and veins in serpentine, also in nodules in various other rocks, particularly those of the Floetz-trap formation. It is found in Cornwall at the Lizard Cape, imbedded in serpentine, also at Portsoy, in Scotland, in serpentine, and in the Isle of Skye in wakke. It abounds in the principality of Bareuth, in Saxony, Bohemia, Norway, Sweden, and France.

The white varieties and those that become so by calcination, are employed in the manufacture of the finest porcelain. Other varieties are said to be used for fulling.

STEEL. See Iron.

STEEL ORE.

A common name for spathose iron ore: see Iron, p. 516.

STILL. An article of chemical apparatus. See the Appendix.

STINKSTEIN. See Swinstone.

STILBITE. See Zeolite.

STRAHLSTEIN. *Actynolite*, Kirw. *Actinote*, Hauy. *Rayonnante*, Broch.

Of this mineral there are the three following subspecies.

1. *Subsp.* Common Strahlstein.

Its colour is olive or leek green, mountain green, blackish green, reddish, yellowish, or greenish white, liver brown, and reddish brown. It occurs in mass, disseminated or crystallized. The primitive form of its crystals is a very oblique rhomboidal prism, the alternate angles of which are 124° and 56°. Sometimes the prism is truncated on its acute lateral edges as well as on its terminal angles and edges. It also occurs in slender needle-shaped crystals. The crystals are striated longitudinally, and are very brilliant externally. Internally this mineral is more or less shining, with a vitreous lustre. Its fracture is broad radiated, either parallel, diverging, bundled, or in stars, very rarely lamellar. Its fragments are sometimes wedge shaped, but more commonly indeterminate, blunt edged. It occurs in wedge shaped prismatic, and in granular distinct concretions. The crystals are translucent, and even semi-

transparent: the other varieties are only translucent on the edges. It is considerably hard and brittle. Sp. gr. 3.—3.3.

It is fusible before the blowpipe into a vitreous scoria of a black or grey colour.

Its component parts according to Bergman are

64.	Silex
20.	Magnesia
2.7	Alumine
9.3	Lime
4.	Oxyd of Iron
100.0	

The massive varieties occur in beds in primitive mountains, accompanied by galena, pyrites, and magnetic iron ore: the crystallized varieties occur in dolomite, foliated talc, and in veins of the oldest formation, accompanied by mica, titanium, &c. It abounds in the Tyrolese Alps, particularly in the Zillerthal, also in the Italian Alps, in Saxony, in Norway, and in some parts of the north of Scotland.

2. *Subsp.* Asbestiform Strahlstein.

Its colours are greyish or greenish white, reddish or yellowish white, olive green, mountain green, smalt blue, and liver brown. It occurs in mass, disseminated, and sometimes in brilliant, flexible, elastic, capillary crystals. Internally it is glistening, with a pearly lustre. Its fracture is divergingly radiated, or slender fibrous. It occurs in coarse and wedge shaped prismatic distinct concretions. It is sometimes translucent at the edges, but more commonly opake. It gives a greenish white streak; is moderately hard, approaching to soft; is brittle but not very frangible. Sp. gr. 2.5 to 2.9.

It is fusible before the blowpipe without addition into a black or grey scoria.

It occurs at Raschau in Saxony mixed with green copper ore and pyrites; in Bareuth, mixed with serpentine and steatite: it also occurs in the Bannat.

3. *Subsp.* Glassy Strahlstein. *Epidot*, Hauy. *Acanticonite*,—*Arendalite* of some authors.

Its colour is olive green, passing into grass green, mountain green, and brownish green. It occurs in mass, or crystallized in hexahedral prisms, often laterally aggregated. The surface of the crystals is smooth and brightly shining. Internally it is more or less shining with a vitreous lustre. Its fracture is between radiated and fibrous. It occurs in slender prismatic, or granular distinct concretions. Its fragments are splintery and wedge shaped. It is translucent passing to semitransparent: is moderately hard, very brittle, and easily frangible. Sp. gr. 2.9—3.49.

The Arendalite has been analyzed by Vauquelin, and the epidot of the Alps by Collet des Cotils with the following results.

Vauq.		Coll.	
37	—	37	Silex
21	—	27	Alumine
15	—	14	Lime
24	—	17	Oxyd of Iron
1.5	—	1.5	Oxyd of Manganese
98.5	—	96.5	

It occurs in the same situations as the common strahlstein; and also at Arendahl in Norway in veins mixed with quartz, garnets, and magnetic iron ore.

There is a great analogy between the several subspecies of strahlstein, and hornblende, tremolite and asbestus.

STRONTIAN.

This alkaline earth was first procured from its native carbonat found at strontian in Argyleshire, whence its name. It has since been found near Bristol and in various other places, combined with sulphuric acid. The pure earth may be obtained either from the carbonat or the sulphat by the same processes as those employed in procuring pure Barytes: as the native carbonat of strontian is however considerably rarer than the carbonat of barytes, the most economical method upon the whole of preparing pure strontian is to mix the native sulphat of this earth (being previously well levigated) with twice its weight of crystallized carbonat of potash, and expose the mass to a moderate red heat for half an hour in a silver crucible, or boil it for an hour with distilled water. By this process a double decomposition takes place, the sulphuric acid quitting the strontian to unite with the potash, while the carbonic acid of this latter combines with the strontian: the mass is now to be washed with hot water till the sulphat of potash is dissolved out, and nothing remains but carbonat, and probably a little undecomposed sulphat of strontian: diluted nitric acid being now added, nitrat of strontian will be contained in solution: the clear filtered liquor by evaporation and cooling will deposit the salt which it contains in crystals, and these being ignited in a platina crucible till the acid is entirely decomposed and driven off, there will remain behind a somewhat indurated mass of a grey colour, which is pure strontian.

Strontian has a hot pungent acrid taste greatly resembling that of quicklime; when exposed

to the air it soon absorbs moisture and falls to pieces, and in a few days after becomes saturated with carbonic acid. If water is poured upon it when recently calcined, the fluid is eagerly absorbed, a copious extrication of heat takes place, and the mass falls into a bulky powder. Strontian is not very soluble in cold water, an ounce of this fluid at 60° taking up no more than 2.7 grs.[a] This solution is perfectly clear and limpid; it tastes like limewater and changes vegetable blues green like the other alkaline substances. On exposure to the air it becomes covered with a pellicle of regenerated carbonat of strontian, which being removed or falling to the bottom, another succeeds, and so on till the whole of the earth is precipitated in the state of carbonat. Boiling water however takes up a much larger proportion of strontian than cold does, in consequence of which as the solution cools it deposits the excess of this earth in a crystalline state. The forms of these crystals are quadrangular plates either plane or bevilled at the edges, or cubes or parallelopipeds.

These crystals by exposure to the air become of an opake white colour, and soon fall to powder: by this change they lose about 10 per cent. notwithstanding the large quantity of carbonic acid that they imbibe: this loss is entirely water, the recent crystals containing full 68 per cent. of this ingredient. Of these crystals one ounce of water at 60° will dissolve 8.5 grs. and the same quantity when boiling will take up no less than 218 grs.

Strontian combines with all the acids, forming with them neutral salts, which though they bear a general resemblance to those of barytes, yet differ from them in various particulars, for an account of which we refer to the salts themselves.

Silex and alumine are rendered soluble in water by means of strontian in the same manner as by the fixed alkalies and barytes, only a larger proportion is required of strontian than of the rest. Sulphur combines with strontian by fusion, into a sulphuret, or by boiling with a solution of this earth, into a hydrosulphuret. The sulphuretted hydrogen that is disengaged from either the one or the other on the addition of muriatic acid, carries off with it a little strontian, and in consequence burns with a red purple flame instead of the blue flame of pure sulphuretted hydrogen.

Alcohol takes up a small proportion of strontian, and in consequence burns with a purple flame: this character in particular distinguishes it compleatly from barytes which communicates a pale yellow colour to the flame of alcohol.

Strontian when exposed to the blowpipe is not fusible as barytes is, but it emits during the action of the flame an intensely dazzling white light. For further particulars of resemblance and difference between these two earths, see Barytes.

The order of affinity between strontian and the several acids is thus stated by Dr. Hope: sulphuric, oxalic, tartaric, fluoric, nitric, muriatic, succinic, phosphoric, acetic, arsenic, boracic, carbonic.

The affinity of barytes for the acids appears to be in all cases greater than that of strontian for the same: but this latter on the other hand generally takes the precedence of the fixed alkalies, especially where the resulting strontian salt is much less soluble than the corresponding one of potash or soda. But in the attraction for nitric, muriatic, acetic, and succinic acids, the fixed alkalies are considered as superior to strontian. The decomposition however which they are able to effect of these strontitic salts is very imperfect, as was first shown in the case of muriatic acid by Dr. Hope. This able chemist dissolved 200 grs. of native carbonat of strontian in muriatic acid diluted with an equal bulk of water, and when the solution was compleat, he added an excess of liquid potash, but no more than 24 grs. of strontian were precipitated; he then poured in carbonated potash, and 170 grs. of carbonated strontian were obtained. The same experiment was repeated, except that the caustic potash was dropped in very slowly, by which process 74 grs. of strontian were deposited, and the subsequent addition of carbonated alkali threw down 132 grs. more of carbonated strontian.

STRONTIANITE. *Strontianit*, Wern.

Its colour is clear asparagus green, passing to greenish or yellowish white, or apple green. It occurs in mass, the rifts or cavities of which are often lined with bundles of acicular crystals the form of which approaches to the four or six-sided prism. Its longitudinal fracture is narrow, strait, and divergingly radiated, with a shining pearly lustre: the cross fracture is fine-grained uneven, passing to splintery, and its lustre is only glimmering. Its fragments are wedge-shaped or indeterminate. It occurs in thin scapiform, and wedge-shaped distinct concretions. It is more or less translucent, some-

[a] Hope, in Edin. Phil. Trans. for 1798, p. 1.

times, in thin pieces, semi-transparent: it is moderately hard, brittle, and easily frangible. Sp. gr. 3.67 *Klapr.* 3.4—3.64 *Kirw.*

Before the blowpipe it becomes white, and calcines, but does not melt. When strongly heated in a clay crucible it runs into a dense, hard, clear, yellowish green glass, with a loss of 30 per cent. When intensely heated in a charcoal crucible, it becomes of a grey colour, and loses 31 per cent. of its original weight, but does not melt. In diluted nitric or muriatic acids it dissolves readily with a copious effervescence.

It has been analysed by Hope, Klaproth, and Pelletier, with the following results:

Hope.		Klapr.		Pellet.
61.21	—	69.5	—	62 Strontian
30.2	—	30.	—	30 Carbonic acid
8.59	—	0.5	—	8 Water
100		100		100

It has hitherto been found only at Strontian in Argyleshire, in a vein passing through gneiss, and accompanied by galena, heavy spar, calcareous spar, and iron pyrites.

STYRAX. See the articles Resin and Benzoic Acid.

SUBERIC ACID. See Cork.

SUBLIMATE CORROSIVE. See Mercury, *Muriat of*.

SUBLIMATION. *Sublimiren*, Germ.

Sublimation is in the dry way what distillation is in the moist. Thus if a small quantity of sal ammoniac is put into a flask, and heat is applied at the bottom, the entire salt rises in the form of white smoke, and condenses in the upper part of the flask in the form of minute crystalline particles, which is a *sublimate*.

Sublimation is conveniently performed in the small way in common flasks, especially the Florence oil flasks, which being of green glass, bear a low red heat very well.

In the large way, as in the making of camphor or sal ammoniac, it is also performed in very large glass globes or earthen cucurbits, or sometimes, though rarely, in a series of earthen vessels called *Aludels*, for which see the Appendix.

SUCCINIC ACID. See Amber.

SUGAR. *Sucre*, Fr. *Zucker*, Germ.

Sugar if pure is a substance perfectly transparent and colourless when crystallized, but when granular, of a pure glossy white, soluble in water and alcohol, without smell, and with the taste of simple sweetness without any other flavour whatever. It melts by heat into a clear yellowish tenacious liquid, and when kindled burns with a strong flame, and a very pungent acid vapour. With the nitric acid it is convertible chiefly into the oxalic acid. It is a most powerful antiseptic, and is one of the most grateful, and (when in mixture) one of the most nutritive of all the alimentary substances derived from the vegetable kingdom.

Sugar is never found pure and very rarely in a state approaching to purity, for it is always intimately combined with mucilage and other vegetable principles, to which it largely imparts its peculiar taste.

Sugar is very extensively diffused over the vegetable kingdom: in general it is elaborated by the growth of the plants that yield it, being chiefly found when the vegetable has arrived at the state of maturity.

The great sources of sugar are, the common juice or sap of plants, as in the sugar-cane, and maple sap,—the ripe fruit, as in the grape, date, fig, in all of which it exsudes and effloresces on the surface when kept dry—and the root (though in much smaller quantity) as in the beet and parsnip. It is also elaborated during the first germination of most grains, particularly barley, as is seen in the process of malting.

Sugar is scarcely if at all contained in any part of the animal kingdom (honey belonging certainly to the vegetable) except in milk, and in the urine during that singular disease, the diabetes mellitus.

As almost all the sugar used by man is obtained from the sugar-cane, we shall first describe the whole process of obtaining it from this most excellent vegetable, and also from a few other sources though of trifling importance compared with the first.

The sugar cane[a] (*Saccharum Arundinaceum*) is a jointed reed terminating in sharply serrated leaves. The body of the cane is strong, brittle, and when ripe of a fine straw-colour, and it contains a soft pithy substance which affords a large quantity of that sweet luscious agreeable juice from which the sugar is manufactured. The average height of the mature cane varies from 3½ to 7 feet, or sometimes much higher, and in rich lands it puts forth a profusion of suckers from which the plant is propagated.

[a] Edwards's History of the West Indies.

The entire cultivation of the sugar-cane is laborious and expensive, but does not belong to the present subject. The canes when ripe are cut close to the root and are passed between iron cylinders in a very powerful mill, by which all the juice is pressed out, and the cane itself is so broken down and compressed as to be quite dry and powdery. It is then called *cane trash*, and is used as fuel in the subsequent operations.

The cane juice consists of water, holding dissolved a quantity of pure sugar, of tenacious mucilage, and of essential oil, but no very exact chemical analysis has been made of it. The proportion of sugar in good cane juice may be reckoned about one-eighth in weight, for (in Jamaica at least) a pound of sugar from a gallon of juice is reckoned a good yield. The juice besides has many impurities suspended in it, such as pieces of the cane leaf and stalk, a black, hard, probably siliceous crust, which surrounds the joints of the cane, and common dirt of the soil. It is the object of all the subsequent process to separate the pure saccharine part from the other ingredients.

As cane juice is extremely liable to fermentation, it could not remain at rest in any quantity for twenty minutes without fermenting, therefore the canes are both pressed as soon as cut, and the juice passes to the boiler immediately after it is delivered from the mill. The boilers are large copper pans called *clarifiers*, with a fire beneath, the fuel of which is the cane trash. When the clarifier is filled and the fire lighted, the *temper*, which is Bristol lime slacked till it falls to powder, is added, with the intention of neutralizing the superabundant acid supposed to exist in the juice. From half a pint to a pint of lime is allowed for every 100 gallons of liquor. As the liquor grows hot a thick scum rises to the surface, and the heat is raised nearly to boiling, but not entirely, that the agitation of boiling may not break the scum and again mix it with the liquor. After about forty minutes from filling the copper the fire is damped, and when the liquor has remained at rest for an hour, the clear part is drawn off with a syphon, the scum falling down unbroken to the bottom. The liquor (if the canes were good) is now clear and nearly transparent, and passes immediately to the *grand* or *evaporating* copper. Here the juice is brought to boil as soon as possible, and as the scum rises it is continually taken off, till the liquor is sufficiently reduced by evaporation to be contained in a second and smaller copper into which it passes, and where it is further reduced by boiling, with occasional addition of lime-water if it continues foul, till the quantity is no greater than will fill the last and smallest copper called the *teache* where the last evaporation is conducted. The colour of the juice progressively deepens as it becomes more concentrated. In the *teache* the juice is evaporated till it becomes extremely thick and tenacious, and is now so saturated with sugar that the latter will separate in distinct grains on cooling. The way of judging when the thickening of the hot liquor has arrived at this point is, to take up a little of it with a ladle, and as it cools to moisten the finger and thumb with it, and draw it out in a thread till it breaks, the length of which depends on the thickness of the liquor.

The whole of the contents of the teache are then emptied into shallow wooden coolers, where the sugar *grains* or runs into a coarse irregular mass of imperfect crystals involved in a dark treacly fluid.

The sugary mass is then passed to the curing house, which is a large airy building, provided with a capacious cistern, the sides of which are sloped and lined with tarrass. Over this cistern is a frame of massy joist-work, on which are arranged a number of empty hogsheads without headings, in the bottoms of which holes are bored, through each of which the stalk of a long plantain leaf is thrust, that serves as a strainer. The granular mass of sugary extract is then laded out of the coolers into these hogsheads, where the melasses or treacley part gradually oozes through the spongy stalk of the plantain, and drops into the cistern below, and the granulated sugar remains. In about three weeks the sugar is tolerably dry and fair, and is then fit for exportation as *Raw* or *Muscovade Sugar*.

Raw sugar is a yellow granular mass, more or less brown according to its purity, clammy to the touch, resembling coarse sand in appearance, and evidently composed of roundish grains of sugar of different sizes and hardness.

All the subsequent refining of raw sugar to bring it to the state fit for consumption is performed in this country, but in the French West India Islands, much of the raw sugar undergoes the further operation of *claying*, by which it is purified to a great degree, and becomes whiter and cleaner by the separation of a large portion of the melasses, and is universally used in that state to sweeten coffee and for most domestic purposes. This process produces

the moiſt granular ſugar, ſimilar to that called in this country *Liſbon ſugar*, which is highly agreeable and uſeful, though it is far ſhort of the purity of the loaf ſugar. The clayed or Liſbon ſugar is made in the following way: A quantity of ſugar from the cooler, inſtead of going to the common curing houſe, is put into conical earthen pots with the points (perforated with a ſmall hole) ſet downwards and immerſed a little way in other earthen jars to receive the drippings. This hole is at firſt cloſed with a plug, till the warm thick ſugar liquor has become ſolid by cooling, which is known by the cruſt at top falling in. The plug is then drawn, and the ſyrup allowed to drain into the pots below for ten or twelve hours. After this, ſome clay mixed with water to the thickneſs of cream is poured on the top of the congealed ſugar, and the water from the clay oozing down through the ſugar, carries out with it at the plug hole, moſt of the melaſſes that the mere draining would not ſeparate. The claying is repeated a ſecond or third time, by which the ſugar remaining beneath it is made very white and pure. The pots remain for twenty days in this ſituation, after which the ſugar is taken out, dried in the ſun for ſome hours, and then taken to a large ſtove-room, where it is kept in a pretty ſtrong heat for three weeks.[b]

The Cochin Chineſe prepare a very excellent moiſt ſugar remarkably cheap, by a very ſimple proceſs which acts ſimilar to the claying.[c] The grained ſugar after the groſs ſyrup has drained off from it, and it has become conſiderably ſolid, is placed in layers of about an inch thick, under layers of equal dimenſions of the herbaceous trunk of the plantain tree, the watery juices exſuding from which, act like claying, and leave the ſugar very white, and porous like a honeycomb. It is ſufficiently pure to diſſolve in water without leaving any ſediment.

All theſe methods however will not produce a hard white-grained full-bodied ſugar comparable to the fineſt loaf-ſugar as is made in this country, for the moiſt ſugars are ſtill conſiderably loaded with melaſſes, and are particularly inferior to the loaf in preſerving all kinds of fruits and vegetables.

The following is the general method of making loaf-ſugar in England, which is on the whole extremely ſimple in theory, though a good deal of ſkill is required in the management.

The raw ſugar is firſt coarſely ground, and about three hogſheads of it are put into a copper pan and diſſolved in lime-water. Some coagulable ſubſtance is then uſed to clarify it. The whites of eggs are on the whole the beſt for this purpoſe, and large quantities of ſea-birds' eggs uſed to be imported into London for the purpoſe, but being expenſive, bullocks' blood is now almoſt univerſally ſubſtituted to eggs which is mixed thoroughly with the diſſolved ſugar. It is then brought nearly to boiling, during which the blood coagulates and carries up with it, in the form of a tough ſcum, moſt of the impurities of the ſugar. This ſcum is ſeparated by ſtraining the whole through a blanket, and the clear liquid is now fit to be boiled down. This evaporation is performed in the copper pans at a boiling heat, a neceſſary inconvenience of which, however, is that the heat required gives a dark colour to the maſs, which muſt conſiderably lengthen the future operations. The ſugar-boiler judges by the appearance and thread of the ſyrup when it is boiled enough, at which time it is very thick and rich, and its boiling temperature is about 232°. It is then let off into a large cooler, and when it is judged to be ſufficiently cooled, it is ſtirred for a conſiderable time with wooden paddles fixed to long poles till the ſugar begins to granulate, and the whole mixture to become thick and opake. This occurs when the temperature has fallen to about 190°, and it is then fit to be poured into the moulds. Theſe are large conical earthen pots with a hole through the cloſed or ſmaller end, and of different ſizes, thoſe intended for the fine loaf ſugar holding about 10 or 12 lbs. of ſyrup, and about twice as much for the inferior lump ſugar. Each of theſe has its earthen jar beneath, into which it deſcends low enough to be firmly ſupported, and which is intended to receive the drainings of the ſyrup or treacle. The moulds with theſe pots are ranged in cloſe rows in all the ſtories of the building above the ground floor (where the pans and furnaces are fixed) and the whole houſe is heated by iron flues, to keep up a pretty warm temperature during the whole time that the ſugar is preparing.

The ſyrup, thickened by ſtirring, and cooled down to about 190°, is then poured into the moulds, the bottom hole being firſt plugged up, and in about four hours the contents have hardened into a ſolid maſs of ſugar, except a portion of uncongealable ſyrup which remains at the bottom. The plug is then withdrawn, and the ſugar in the mould is allowed to drain

[b] Dict. d'Hiſt. Nat. Article Canne.

[c] Macartney's Embaſſy to China.

for about 36 hours undiſturbed. The *green ſyrup* as it is called, or that which falls during all this time, is carefully collected and kept apart from the coarſer ſyrups. It is browniſh, but free from any burnt taſte, and is ſtill very rich in ſaccharine matter. It is uſually mixed in certain proportions with the raw ſugar in the next boiling, ſo that in fact the contents of every boiling conſiſt of raw ſugar and the ſyrups of previous operations in regular ſucceſſion.

The ſugar from which the green ſyrup has ſubſided is now of a better colour, and much purer than the raw ſugar, but it is brought to its higheſt degree of purity by claying.

A mixture of pipe-clay and water is then poured on the ſurface of the mould and allowed to remain for four or five days, during which the clay dries, ſhrinks, and at laſt readily comes off in a ſolid cake. In general two more clays are added ſucceſſively at the ſame interval. If the loaf is examined in different periods of the claying, the upper, or broader end, will be found hard and white, and the brown treacly ſyrup which it is the object of claying to get rid of, will be ſeen gradually ſettling towards the point of the loaf, and at laſt will be totally expelled and fall into the pot below. A fine loaf therefore is not conſidered as perfectly clayed till the lower part fully equals the upper in whiteneſs. There is alſo conſiderable difference in the colour and fineneſs of the ſyrup during the ſucceſſive clayings, that of the firſt clay being in this caſe the coarſeſt; and the others much purer, for the two laſt clays are only employed in cleaning the very point of the loaf, ſo that the ſyrup from theſe muſt contain a good deal of pure ſugar which the moiſture from the clay has diſſolved before it reaches the ſyrup. When the claying is compleated the moulds are left undiſturbed for a day or two, after which the loaves of ſugar are turned out, and are then ſolid, white, and pure. To dry them compleatly they are put for three or four days in a ſmall chamber heated by a ſtove ſo ſtrongly that a perſon unuſed to it could hardly remain in for half a minute, and here the ſugar is rendered much more hard, white, and beautiful. It is then taken out, and is fit for ſale.

All the ſyrups and runnings from the moulds are more or leſs rich in ſugar, and are all treated in a ſimilar manner with the raw ſugar, to make loaves or lumps of inferior quality, and the ſyrups from theſe again are worked as before for a ſtill coarſer kind. The moſt ordinary loaves are called *baſtards* and are made entirely from the green or firſt ſyrups of the coarſer loaves, without any admixture of raw ſugar. The baſtard loaves require more heat than the finer ſorts, the treacly part being much more viſcid, and they remain longer on the moulds before claying. They are alſo only ſlightly clayed, for the runnings from theſe form *common treacle*, the price of which is ſo much inferior to any ſolid ſugar, however brown, that it is an object to the manufacturer to leave as much treacle as poſſible in the coarſer loaves, conſiſtently with giving them a ſaleable colour and grain. Hence the texture of theſe loaves is much ſofter and more open, and the grain looſe. The lower part of the baſtard loaves, which is much more diſcoloured than the upper, even after claying, is cut off, and when ground it forms the moſt ordinary kind of moiſt ſugar, and the upper part of the ſame loaves forms the common moiſt ſugar. But the fineſt white moiſt ſugar is clayed muſcovado, prepared in the French manner in the Weſt Indies, as already mentioned.

Sugar Candy.

Sugar candy is ſugar brought to a regular form by ſlow cryſtallization. The management of it differs conſiderably from that of loaf ſugar. To prepare it the ſyrup is clarified as uſual, and boiled down to a certain point, but not ſo much as for making loaf ſugar. It is then poured into large oblong moulds or boxes, into which a light frame is previouſly fixed, holding ſtretched from one end to the other a number of cords of packthread. The mould filled with ſyrup, is then put into the drying ſtove, and ſuffered to remain undiſturbed for a conſiderable time, during which the ſugar gradually depoſits in cryſtals around the threads. The mould is then removed, and the frame is lifted out, with every thread thickly and very beautifully encruſted with the candy, and is afterwards drained to free it from the adhering ſyrup. Sugar candy differs from common ſugar in being much harder and tranſparent. The brown ſort cryſtallizes full as regularly as the white, but becomes clammy and deliqueſcent in a damp air, whereas the white candy remains always dry. On account of its ſuperior hardneſs it is leſs eaſily ſoluble than the loaf ſugar, and appears to have much leſs taſte, but it has full as ſtrong a body of ſugar, and would be excellently calculated for preſerving all vegetable food, if the price was lower. The ſole difference between the white candy and the fineſt loaf appears to be in the form, which in the candy is the natural ſaline form of ſugar, but

in the loaf is granular, owing to the agitation given to it for this expreſs purpoſe whilſt cooling. The commoneſt form of the regular cryſtals of ſugar candy is an oblique four-ſided priſm, terminated by dihedral ſummits.

A valuable ſugar is extracted in many of the States of North America, from the juice or ſap of the ſugar-maple.[d] The tree is tapped with an augre, which is introduced about two inches, and a projecting ſpout is made below it, under which troughs are ſet to catch the juice. The ſeaſon for tapping is from February to April, for about ſix weeks, during which time a moderate-ſized tree will yield from 20 to 30 gallons of ſap, from which may be made about 5 or 6 lbs. of pretty good ſugar. During the reſt of the year the ſap will flow from the wound, but it is too thin and watery to be uſed with advantage for making ſugar. This evacuation does not appear at all to injure the tree, for the ſame proceſs may be repeated every year for a great length of time; and the juice is even more ſaccharine from the trees that have been previouſly wounded, than from the freſh trees.

This juice is clear, pleaſant-taſted, and highly ſaccharine. It is made into ſugar by the farmers in the country, and with a ſimple apparatus. It is uſually clarified with lime and white of egg (or milk) boiled down, grained and clayed, in the manner of the cane juice. Another method occaſionally practiſed is, to reduce the quantity of liquid by freezing, where the ſeaſon will allow of it, which is preferable to entire evaporation and cheaper. The common maple ſugar is clean-looking, and very ſweet, but with a peculiar though not unpleaſant taſte. It may be made into loaf ſugar probably equally well with the muſcovado, but it is chiefly employed in a half purified ſtate, like the common moiſt ſugars. The maple juice will alſo furniſh a pleaſant wine by fermentation and a good vinegar.

The ſaccharine quality of the juice appears to be highly improved by careful cultivation of the tree.

Among the vegetables indigenous to the middle and north of Europe, which are ſenſibly ſaccharine, the beet root is found to exceed them all in the quantity of ſugar which it contains. This was aſcertained by Marggraf,[e] in ſome valuable experiments made with a view of diſcovering ſome native ſugar which might be a ſubſtitute for the foreign ſugar, when the latter is expenſive and beyond the reach of the peaſant.

Two methods were purſued by this accurate chemiſt. One was to dry a given portion of the vegetable, to boil it in rectified alcohol, and then keep the alcoholic ſolution at reſt for a time, by which the ſugar will ſeparate in cryſtalline grains. This mode however is much too expenſive to be purſued in manufacture, but it ſerves as an uſeful indication of the *comparative* proportions of ſugar in different vegetables, though the *actual* quantity obtainable by the uſual mode of manufacture appears to fall far ſhort of what is yielded by treatment with alcohol.

The other method was to imitate in the ſmall way the proceſs performed on the ſugar cane juice, which alſo was attended with a certain degree of ſucceſs. The experiments of this celebrated chemiſt are the following: three roots were ſelected, the white beet, the red beet, and the ſkirret, all of which give evident indications of abounding in ſugar, for when cut in ſlices and dried their taſte is very ſweet, and the microſcope ſhews a number of cryſtalline grains of ſugar diſperſed through their ſubſtance.

Some ſlices of white beet thoroughly dried but not burnt, were powdered coarſely, and 8 oz. of this powder again dried, were put into a bottle with 16 oz. of highly rectified alcohol, and being looſely ſtopped, the liquor was ſlowly brought to boil on a ſand-bath, with frequent ſhaking. The veſſel was then removed, the ſolution filtered, and the powder preſſed ſtrongly to ſqueeze out all the liquor. This clear ſolution was then put into a bottle which was corked, and ſet by in a cool place. A cryſtallized ſalt depoſited gradually in the courſe of ſome weeks, which was hard and tolerably pure ſugar. This was rediſſolved and again cryſtallized in the ſame way, by which a very pure ſugar was obtained. In this way 8 oz. of the white beet root gave half an ounce or $\frac{1}{16}$ of ſugar; 8 oz. of ſkirret root equally dried, gave 3 drams, or about $\frac{1}{21}$ of ſugar; and the ſame quantity of the red beet gave only $2\frac{1}{2}$ drams, or about $\frac{1}{26}$ of ſugar. The ſolution however ſtill contained a quantity of ſugar mixed with the reſinous part of the root, and if it is evaporated to dryneſs, a ſweetiſh uncryſtallized extract remains.

The ſkirret root was then treated in the following manner without alcohol, with a view of extracting the ſugar. A quantity of it was chopped ſmall, bruiſed in a mortar, and the juice expreſſed through a cloth bag, and the pulp was

[d] Dr. Ruſh, Phil. Mag. vol. 1.

[e] Mem. de l'Acad. de Berlin, for 1747.

again moistened with water and expressed to get out all the saccharine liquor. The whole liquor was then kept at rest for 48 hours, in a cool cellar, by which most of the feculence subsided, and the clear liquor was carefully drawn off. The author lays much stress on this part of the process, which, if it is not done properly, considerably hinders the subsequent production of the sugar. The clear liquor was then heated in a copper pan, clarified with white of egg, and boiled down to the consistence of thick syrup, and kept in this state for about six months in a warm place, by which it concreted into a semi-fluid crystalline mass, composed of impure crystals of sugar and a good deal of syrup. The whole mass was then a little warmed, to give the syrup a little more fluidity, and poured into a funnel-shaped vessel of tinned iron, with holes at the sides and bottom, and set by in a warm place; by which, after a considerable time, the impure uncongealable syrup slowly filtered to the bottom, leaving the purer saccharine part in the form of a brown granular mass. The latter was then redissolved in water, again clarified with white of egg, strained, boiled with a little lime, again strained, and then evaporated to a thick consistence, and stirred till cold. A sugary viscid mass still purer than the last was thus obtained, which, on being kept for a week in a funnel-shaped pot with a single hole at bottom, plugged up, congealed into a grained sugar equal to good muscovado, from which a syrup separated and dropped through when the plug was withdrawn.

Such is the process of this chemist to obtain a sugar from the skirret root, and he proceeded in the same manner with the white and red beet root, and with the same success. He further observes, that he rasped the beet roots, being harder than the skirret, that the mucilaginous deposit from the beets was browner and less copious than from the skirret; the sugar from the white beet was the most abundant and the purest, and that from the red beet was the least so. The mucilage or sediment from the skirret washed with cold water and purified, yielded a very good white farina.

All these roots are very watery. The white beet loses by gentle, but entire, desiccation, full three quarters of its weight, and the red beet seven eighths.

Mr. Achard, of Berlin, a few years ago directed his attention to the extraction of sugar from the beet in the large way, and his success was so great that a reward was given to him by the Prussian government for his elaborate experiments; which it was hoped would enable the Continent of Europe to supply itself with sugar from the produce of its own soil, and to be no longer dependent on the West Indies for this essential article of food. The experiments were made on a sufficiently large scale, and the success was such as to require some notice in this place, but as several years have elapsed since these trials were made known to the world, without being followed by any general attempts to pursue them, we must conclude that the expence and trouble of obtaining sugar from this source are as yet more than the cost will repay, especially during the present comparatively low price of West India produce.

The plant which yields this sugar is the *white beet*, the root of which resembles the parsnip in shape, and is white crossed with bands of red, and has a mild sweetish taste. It is remarkably succulent, and the saccharine quality of the juice seems to be much improved by careful cultivation in a rich soil. It has long been cultivated in many parts of Germany as food for cattle.

The process given by Achard for extracting the sugar is the following.[f] The roots are pulled, cleaned, the leaves stripped off, and then boiled for a short time, till they are so far softened that a straw may be thrust into them. They are then sliced by a machine used in the country for slicing potatoes, and put under a very strong press to extract the juice. The cake which remains in the press still retains enough juice to make it worth while to moisten it with water and after some hours again to press it; this juice is mixed with the former. Even after this second pressing the cake may be usefully employed in making a fermented liquor, from which a spirit may be extracted by distillation.

The juice is then strained through a flannel, boiled down to two-thirds of its original bulk, again strained through a thick blanket, and then boiled down to half its bulk, and strained. It is now of the consistence of a thin syrup, and must be put in shallow pans in a stove-room, heated to about 120°, to allow the sugar to crystallize. This begins by the formation of a hard crust on the surface, which must be now and then broken down to hasten the evaporation. After a time there forms on the surface a thick gummy skin, instead of a hard granular crust; when this appears, the syrup is removed from the stove-room, and the whole mass is put into a close linen sack

[f] An. Chem. tom. 32.

previously wetted, and strongly, but gradually pressed. By this the syrup is forced through the sack, and there remains within it a yellow granular saccharine mass, resembling muscovado sugar, very sweet and well tasted. From this, sugar of any degree of fineness may be afterwards made by the processes commonly employed in the refining of cane sugar.

Such is the process of Mr. Achard, which was repeated by a commission from the French Institute,[g] with similar results as to the general products, but the quantity yielded was much less than what might be inferred from the price which Mr. Achard gives as the first cost to the manufacturer.

According to these subsequent experiments, pursued precisely in Mr. Achard's method, 1152 parts of the fresh beet root yielded 18 parts of raw muscovado, which was brown and ill tasted, and would require successive purifications, with the loss of from $\frac{1}{3}$ to nearly $\frac{1}{2}$ its weight, to bring it to the state of fine saleable sugar.

It should be mentioned that the uncrystallized syrup and all the refuse, afford excellent materials for fermentation, and hence for the production of ardent spirit, or a kind of rum.

Experiments on the extraction of sugar from the white beet have also been made in the large way by Professor Lampadius of Freyberg, the results of which are represented as very favourable to the undertaker. As the process employed somewhat differs from that of Mr. Achard, we shall give it in a few words.[h,i] He took 100 lbs. of fresh beet roots, peeled, rasped, and expressed them, and obtained 44 lbs. of juice. This he put into a boiler, and added to it 44 oz. of broken charcoal, previously made red-hot in the fire, and sifted when cold to separate and reject the fine powder. This he boiled for a quarter of an hour and strained the juice through flannel, and again returned the clear juice into the vessel and boiled it down to the consistence of syrup. This was set by in a cool place for a fortnight, during which it granulated, and the whole was strongly pressed through a cloth to separate the syrup from the congealed sugar. The latter was then redissolved in hot water, scummed while boiling, clarified by lime-water and blood, and again set by for 48 hours to granulate. The crystals were now larger and of a better colour than before, and were again boiled with lime-water and a pint of skimmed milk, and cooled as before, by which a blueish saccharine mass was obtained, which, when congealed in a mould, gave a loaf of tolerable sugar weighing 4 lbs. the taste of which was precisely the same as that of common sugar of equal fineness.

In another experiment conducted in a similar manner only $3\frac{1}{2}$ lbs. of sugar was obtained.

On repeating these experiments in the large way, with several improvements in the apparatus and process, he obtained (as he asserts) from 100 quintals of beet root, 200 lbs. of brown sugar, which, purified to a considerable degree, were reduced to 180 lbs. This proportion is much inferior to that of the former experiments.

The use of the charcoal is to destroy a quantity of colouring matter, and also a bitter unpleasant taste which the beet contains. The power of recently heated charcoal in clarifying saccharine liquors, and depriving them of all foreign colour, smell, and taste, has been already mentioned in this work under the article *Charcoal*, p. 238, to which it may be added that attempts have been made to introduce it into the sugar refineries in this country, but whether from the expence and bulkiness of the charcoal, or from the difficulty of persuading workmen to alter their accustomed habits, the plan has never been carried into practice. In experiments in the small way the clarifying power of charcoal is very striking and easily shewn, for if a funnel lined with filtering paper, is filled with fresh-burnt charcoal bruised to a pretty fine powder, and a solution of the coarsest brown sugar be poured on it, as it drops through the funnel it appears fine, limpid, and nearly colourless. The same effect is produced more rapidly by boiling the syrup with the charcoal for a few minutes and straining.

Professor Lampadius also suggests the advantage of reducing the bulk of the saccharine juice by freezing, which if not urged too far, will separate much of the watery part in the form of ice, so that less fuel will be required in the evaporation.

This chemist however candidly confesses that in one experiment made on 100 quintals of the root, the sugar obtained sold for somewhat less than the entire cost of the materials and the process, but this was in a cold unfavourable year, and did not include the profits to be made from all the residues in yielding ardent spirit, &c.

Physical and Chemical Properties of Sugar.

Pure sugar appears either in a regularly crystallized form, or in shining white crystalline grains. Both in candy and in loaf it is very

[g] An. Chem. tom. 35. [h] Journ. de Phys. tom. 50. [i] An. Chem. tom. 38.

hard and brittle. It is void of smell, and its taste is that of pure sweetness. When hard loaf sugar is rubbed in the dark it is highly luminous.

Sugar is very soluble both in water and alcohol. The watery solution may be preserved for a length of time unaltered if the sugar is pure, but if it is mixed with mucilaginous, farinaceous, or other matters, it readily enters into the vinous fermentation. In this process the strength of the liquor and quantity of alcohol produced, depend directly on the quantity of sugar present, whence the most essential part of the process of vinous fermentation is reasonably inferred to be the conversion of sugar into alcohol. From comparing the products with the materials of fermentation, Lavoisier concluded that sugar was a triple compound of 28 parts (by weight) of carbon, 8 parts of hydrogen, and 64 parts of oxygen.

Sugar melts at a heat considerably above that of boiling water, and forms a blood-red viscid fluid, which when cooled has a not ungrateful flavour of empyreuma mixed with the natural sweetness. When melted, it takes fire on applying a lighted substance, and burns with a strong red flame, and a peculiar and very penetrating odour which excites coughing, and is owing to the production of an acid.

If sugar is distilled *per se* from a glass retort with a heat gradually increased to redness, and the products carefully collected, they will be found to be, first a coloured liquor strongly acid and pungent, which is called the *Pyromucous*, being the same as is furnished by mucilage under a similar treatment. A large quantity of gas comes over at the same time, which is hydro-carbonat mixed with a little carbonic acid, and a very pure charcoal is left behind, which burns away in the open air without leaving any residue.[a] Neither azot, ammonia, nor lime, or any other substance, is obtained in this process; so that sugar is one of the purest hydro-carbonous oxyds that we know.

Under the article *Mucilage* we have mentioned in part the very interesting researches on the comparative nature of sugar and gum or mucilage, carried on by the last mentioned eminent chemist. It was there mentioned that sugar by being treated with phosphuret of lime (a disoxygenating substance) lost its saccharine nature, and was converted into a clammy substance no longer soluble in alcohol, which strongly resembled mucilage. The converse of this experiment however, (that is of converting mucilage into sugar by an oxygenating substance) would not answer, for when nitric and oxymuriatic acid were passed through a solution of gum-arabic in various ways, nothing saccharine could be observed, but the whole was converted into the oxalic and other acids.

The actual chemical differences between mucilage and sugar, as found by Mr. Cruikshank, are the following: sugar is soluble both in water and alcohol, and crystallizable from either solution; but mucilage is insoluble in alcohol, and refuses to crystallize from its watery solution. 480 grs. of sugar yielded by distillation 120 grs. of charcoal, 270 grs. of liquid pyromucous acid, 41 oz. measures of carbonic acid gas, and 119 oz. measures of hydro-carbonat gas:—the same quantity of gum arabic yielded 96 grs. of charcoal, 210 grs. of pyromucous acid, 93 measures of carbonic acid, and 180 of hydro-carbonat. It also gave about 10 grs. of lime, and the acid when saturated with lime gave out a little ammonia, and hence lime and azot are substances that belong to mucilage and not to sugar.

The habitudes of each substance with nitric acid also differ considerably, as already mentioned in part under the article Mucilage. When gum-arabic (for example) is heated with nitrous acid only till nitrous gas begins to be disengaged, a quantity of white insoluble matter precipitates which is the *Mucous* acid, and the residue is malic acid which a further addition of the nitric converts into oxalic. But sugar is changed into oxalic, or malic and oxalic acid, without the production of any mucous acid. The quantity of oxalic acid produced from a given weight of sugar with nitric acid also exceeds that yielded by the same weight of mucilage with the same proportion of acid.

In the spontaneous changes also sugar and mucilage differ essentially. Sugar being the essential material of the vinous fermentation, but mucilage is incapable of this process when pure, and appears to contribute little to the generation of alcohol when in combination with fermenting materials.

SUGAR, *Acid of.* See OXALIC ACID.

SUGAR, *Empyreumatic Acid of.* See SUGAR and PYROMUCOUS ACID.

SUGAR OF LEAD. See LEAD.

SUGAR OF MILK. See MILK.

SULPHUR, *Brimstone. Soufre*, Fr. *Schwefel*, Germ.

Sulphur is found both in the mineral, vegetable, and animal kingdoms, in the two latter however it occurs so rarely that all the vast

[a] Cruikshank in Rollo's Essay on Diabetes.

commercial demands for this ſubſtance are ſupplied from the former ſource. Of mineral ſulphur there are two great families, firſt, *native ſulphur*, or uncombined with any conſiderable proportion of other ingredients. Secondly, ſulphur in union with metallic baſes, forming the various *pyrites and ſulphurated ores*. Of theſe, the latter are deſcribed under the various metals from which they derive their ſpecific characters; the former we ſhall now proceed to give an account of.*

The colour of native ſulphur is a pale ſlightly greeniſh yellow, paſſing on one hand into grey, and on the other into lemon yellow. It occurs in maſs, diſſeminated, in rounded fragments, cellular, ſtalactitic, ſuperficial, and cryſtallized. Its primitive form is a very acute octohedron compoſed of two tetrahedral pyramids with ſcalene triangular faces joined baſe to baſe; the common baſe of the two pyramids is a rhomb, the two diagonals of which are to each other in the proportion of five to four. The other varieties of cryſtallization that it preſents, are the following.

1. The primitive figure with the ſummits truncated.

2. The ſame as the preceeding with a low tetrahedral pyramid ſet upon the terminal truncatures.

3. The primitive figure with two oppoſite ſolid angles of the common baſe truncated.

4. The primitive figure with a tetrahedral priſm interpoſed between the pyramids.

5. A cuneiform octohedron.

6. A cuneiform hexahedron.

The cryſtals are generally ſmall and ill defined, but thoſe from Sicily are for the moſt part perfect, and are ſometimes full five inches in length. They are generally grouped together. The cryſtals externally are very brilliant, with a luſtre between reſinous and adamantine; the other varieties are more or leſs gliſtening. Its fracture is fine-grained uneven, paſſing on the one hand to conchoidal, and on the other to ſplintery. The cryſtals are often ſemi-tranſparent, the other varieties are more or leſs tranſlucent. It is ſoft, brittle, and eaſily frangible. Sp. gr. 1.99—2.03.

Sulphur by friction acquires the reſinous electricity; the tranſparent cryſtals are in a high degree double-refractive.

Sulphur is found ſometimes, though rarely, in veins in primitive mountains, its common repoſitory is in beds of ſecondary gypſum, where it occurs principally in nodules; it is ſometimes alſo met with in beds of indurated marl and compact limeſtone. Volcanoes alſo abound in ſulphur, which ſublimes in the rifts and cavities of the lava.

Stratified ſulphur is met with in Sicily, at Conilla near Cadiz in Spain, near Bex in Switzerland, in Lorraine, Hanover, Gallitzia, and Poland: volcanic ſulphur is obtained from Etna in Sicily, the Solfatara near Veſuvius, Hecla in Iceland, the Peak of Teneriffe, the Souffriere in Guadalupe, &c.

The proper native ſulphur ſeldom contains any foreign matter except a ſmall proportion of earth; the whole preparation therefore which it requires for the purpoſes of commerce is to be freed from its earth by diſtillation, and then melted and caſt into moulds.

The ſulphur at the Solfatara is in nodules conſiderably mixed with a white earth; theſe being dug up and broken to ſmall pieces, are put into earthen pots arranged in a double row along a very ſimple furnace; the hole in the upper part of each pot by which it is charged is cloſed with an earthen pipe, and a little lute: and on the application of a gentle heat the ſulphur is volatilized, and paſſes through the pipe into an earthen receiver where it concretes; the contents of the receivers are then melted in a cauldron, the impurities either riſe to the top where they are ſcummed off, or ſubſide to the bottom; and the ſulphur thus purified is run into moulds.

In England a large quantity of ſulphur is obtained at a ſmall expence from the pyritical copper ore during the roaſting which this undergoes previous to the proceſs of ſmelting. At the celebrated Parys mine in Angleſey, works for this purpoſe are conſtructed on a large ſcale. At the foot of a low but ſteep ridge of rock, are conſtructed maſſes of maſonry not unlike high blaſt furnaces, except that the top is capped with a dome of brickwork, from which proceeds a horizontal flue, about the ſize of a common chimney, which terminates in a ſquare or oblong brick chamber, built at the top of the rock. Some lighted fuel is introduced by means of a door in the dome of this roaſting furnace, and a few baſketfuls of ore, broken into moderately ſmall pieces, are thrown on it, freſh parcels of ore being added from time to time as the preceding parcels get lighted; a ſufficiency of air for the ſlow combuſtion required in this proceſs, is let in by means of a door at the bottom of the kiln, which alſo ſerves to take out the ore by when

* Hauy, Brochant, Jameſon.

properly roasted; that part of the sulphur which escapes combustion rises in vapour, and collects in the dome (the door of which is only opened to admit fresh charges of ore) whence it passes through the flue into the chamber, where it presently concretes, lining the sides and roof; each chamber has a door by means of which, about once in six weeks, it is cleared of the sulphur. This rough sulphur is in spungy pulverulent crusts, of a dirty greyish yellow colour. For its purification it is melted in a boiler, the impurities are got rid of by scumming and subsidence, and the fluid mass is then laded into cylindrical moulds to form the common roll sulphur or brimstone, or into cones about two feet high forming the loaves of sulphur. The impure dregs are also sold in the shops under the name of *sulphur vivum*.

Besides the common sulphur there are two other forms in which this substance appears in commerce, namely, the sublimed, or *flowers of sulphur*; and the precipitated, or *magistery of sulphur*.

Flowers of sulphur are prepared in the laboratory, by heating in a sand-bath an earthen cucurbit charged with roll sulphur, and surmounted by a set of aludels; at a gentle heat the sulphur first melts, then rises in vapour, and concretes within the aludels in the form of a glittering yellow powder, which when examined by a microscope appears to be composed of minute crystals. Flowers of sulphur are made in the large way by conducting the vapour of melted sulphur into close chambers instead of aludels, and being prepared with less care it is often inferior in purity to that obtained by the former method. Flowers of sulphur, however prepared, are more or less acidulous from a mixture of sulphureous acid, on which account an infusion of them in water, reddens tincture of litmus; this acid, however, may easily be got rid of by washing the powder first with a warm and very dilute solution of pearl-ash, and then with two or three successive parcels of warm water.

Magistery of sulphur is prepared by decomposing by the sulphuric or any other acid a solution of alkaline sulphuret; a copious white precipitate falls down, which is to be thoroughly edulcorated with successive portions of warm water. Sulphur in this state has a dull earthy appearance, owing to its extremely minute state of division; it is of a yellowish white colour, is smooth and almost unctuous to the touch; by exposure to light it acquires a yellow colour. It is generally looked upon as the purest form of sulphur, yet from some of its properties and the mode in which it is prepared, there is some reason for suspecting that a portion of hydrogen enters into its composition.

The sulphur that is procured in the roasting of ores, especially those of copper, is apt to contain besides earthy impurities a very notable proportion of arsenic, while on the other hand the volcanic sulphur in general, and that of Sicily in particular, is entirely free from this contamination. This is the cause of the universal preference given by the manufacturers of sulphuric acid to Sicilian, over English sulphur; and hence it is a matter of some consequence to be able to ascertain in a compendious and satisfactory manner the purity of any particular sample of this substance. The following method will, we believe, be found to answer every practical purpose. Having rubbed to fine powder in an earthen-ware mortar some of the sulphur to be examined, take 100 grs. and put it into a Florence flask with 5 oz. measures of the *best* oil of turpentine; heat the mixture gently over a lamp, or a pan of charcoal, till it has boiled for about a minute, then pour the clear hot solution into a six or eight-ounce vial, stop it with a cork, and shake it till the liquor has cooled down to the temperature of the hand; it will now be quite turbid with sulphur that has separated from the oil during its cooling, and being run through a glass funnel very lightly plugged with fine tow will pass out clear, leaving the sulphur behind. The oil is now to be again transferred to the sulphur remaining in the flask, and to be a second time boiled, cooled and filtered as before. By repeating this process four or five times, there will be left only a brownish orange residue, on which the oil will refuse to act any longer. This residue being laid on a piece of earthen ware is to be exposed to a heat not higher than that of melting lead, till it ceases to exhale any sulphureous vapours; being then rubbed up with a little moistened charcoal, and pressed into the bowl of a tobacco-pipe or any other convenient vessel, it is to be heated nearly red, upon which a white vapour will arise, and show itself to be arsenic by its peculiar garlic odour. The sulphur precipitated from the oil of turpentine may be entirely freed from this latter by exposure to the air and light for a day or two; it will then be of a beautiful sparkling yellow colour (far superior to that of the common flowers of sulphur) and entirely inodorous. The common English brimstone or roll sulphur sometimes contains a full $\frac{1}{15}$ of insoluble resi-

due, chiefly orpiment; the best Sicilian sulphur in small rolls, contains hardly more than 3 per cent. of residue which appears to be little else than earth, as it affords no arsenical odour when heated with charcoal.

To the taste sulphur is perfectly insipid, when broken down however by the teeth, it manifests a peculiar indescribable grittiness, which sufficiently distinguishes it from all other bodies. It is inodorous at the common temperature, but when rubbed a slight fetid smell is sufficiently perceivable; if a roll of sulphur is held for a minute in a moist warm hand, it breaks across with a sharp crackling not unlike the snapping from the discharge of an electrical spark, the hand at the same time contracts a peculiar disagreeable odour, which lasts some minutes. When exposed to a temperature of about 224° Fahr. it melts into a transparent brownish red fluid; by an increase of heat, the fluidity diminishes and the sulphur begins to sublime in visible vapours; when it somewhat exceeds the temperature of 300° Fahr. its consistence will be viscid and thick like treacle, and the vapour will take fire, the inflammation instantly spreading to the rest of the mass.

If a crucible or ladle full of sulphur be allowed to cool gradually, and the fluid central part be let out just before it solidifies, by piercing the outer crust, the cavity will be found to be entirely lined with compressed needle-shaped crystals. When sulphur has become viscid by heat its fluidity may be restored merely by lowering its temperature; if it is kept in this thick state for a few minutes, and then without previous cooling is poured into warm water, it will be of a brown colour, soft and considerably plastic; in this state it is a very useful material to artists and modellers for taking impressions of seals, gems, &c. especially as in the course of a few hours it resumes the hardness and other properties of common sulphur. This soft sulphur is considered by Fourcroy (but we think without sufficient proof) to be an oxyd of sulphur.

Water in the state of steam is partly decomposable by melted sulphur, an inflammable gas, perhaps sulphuretted hydrogen, being produced. With oxygen, sulphur combines in two proportions; if this latter is heated in common air till it becomes thick, it takes fire, burns with a blue flame, and is converted into a pungent highly suffocating acid gas called Sulphureous Acid; if on the other hand it is set fire to in oxygen gas, the flame which it emits is of a reddish purple colour, and the acid produced is Sulphuric mixed with sulphureous.

The chief acids that have any action on sulphur are the nitric, oxymuriatic, and sulphuric. The former is decomposed upon sulphur at a boiling heat, nitrous gas is given out, and sulphuric acid is the result. The second in like manner acidifies the sulphur, but with some peculiar phenomena described under the article Sulphurized Muriatic Acid. Sulphuric acid with some difficulty takes up a small proportion of sulphur, and sulphureous acid is produced, partly from the oxygenation of the sulphur, and partly from the deoxygenation of the sulphuric acid.

The alkalies and alkaline earths combine with sulphur forming the important class of *Alkaline* Sulphurets. Most of the metals and metallic oxyds also combine with sulphur and produce the class of *Metallic* Sulphurets. Sulphur unites with hydrogen, forming Hepatic gas or Sulphuretted Hydrogen. The combinations of sulphur with carbon and with phosphorus, have been already described under those articles.

Sulphur when in fine powder is sparingly soluble by digestion in highly rectified alcohol, but a more concentrated solution is made by presenting each to the other in the state of gas; for this purpose put some sulphur into a cucurbit, and suspend within the same a vial filled with alcohol, then lute on a head and proper apparatus, and proceed to distillation; both the sulphur and alcohol are volatilized, and meeting with each other in the upper part of the vessel combine readily together, and condense in the receiver into a yellowish strongly smelling fluid, from which nearly the whole of the sulphur may be again precipitated by the addition of water.

Oil of turpentine and the other essential oils dissolve a considerable proportion of sulphur when hot, the greatest part of which they again deposit in crystals if cooled slowly. The fat oils unite with sulphur by boiling, and acquire a deep yellowish brown colour, and a strong fetid odour; the combination is generally called *balsam of sulphur*. By long repose in a cool place, it deposits small octohedral crystals of sulphur.

The order of affinities for this substance, according to Bergman is, fixed alkali, iron, copper, tin, lead, silver, bismuth, antimony, mercury, arsenic, and molybdena.

The uses of sulphur are very important. It is employed in medicine; it enters into the composition of sulphuric acid, of gunpowder,

and of the common composition for paying the bottoms of ships. Its fumes when burning, are employed for bleaching silk and wool, and checking the progress of vinous fermentation. Common matches which are in daily use for lighting fires derive their principal utility from being tipped with sulphur.

SULPHUR, *golden, of Antimony*. See ANTIMONY.

SULPHURET.
SULPHURETTED HYDROGEN.
HYDROSULPHURETS, &c.

The various combinations of sulphur with alkaline, earthy, and metallic bases, of sulphur with hydrogen, and the latter compound with the several bases in different proportions of sulphuration, are so intimately connected with each other in chemical enquiry, that we have preferred to give the whole under one article, especially as the subject is somewhat intricate, and requires some attention to be fully understood.

The several combinations which belong to this subject, are

1. *Sulphuretted Hydrogen*, composed of hydrogen holding sulphur in solution, and when uncombined with a base assuming the gasseous form.
2. The *Hydrosulphurets*, or combinations of sulphuretted hydrogen with the several alkaline, earthy, and metallic bases, in which its action strongly resembles that of an acid.
3. The *Sulphurets*, or combinations of sulphur with the alkalies, earths, and metals.
4. *Supersulphuretted Hydrogen*, or sulphuretted hydrogen, with a considerable, but, in general, an uniform excess of sulphur.
5. *Sulphuretted Hydro-sulphurets*, or combinations of sulphur, sulphuretted hydrogen, and the alkaline or earthy bases.

SULPHURETTED HYDROGEN GAS, or *Hepatic Air*. *Gas Hidrogene Sulfuré* of Berthollet, and other French chemists. *Hydrothionic Acid* of some German authors.

The properties of this gas were first explained in a very excellent memoir by Mr. Kirwan,[a] and nearly at the same time by M. Gengembre;[b] and the society of Dutch chemists, and since this period they have been still more fully unfolded by Berthollet, Fourcroy, Proust, and other eminent chemists. The most striking and obvious properties of this gas are the following: it has a most penetrating and offensive sulphureous smell, similar to that of rotten eggs, or a foul gun-barrel when wetted, but somewhat less nauseous; it is rather heavier than common air; it is inflammable, and explodes like hydrogen, only with less violence, when mixed with common air or oxygen; when moderately diluted it may be breathed for a short time without danger; it is absorbed readily by water to a certain extent, and then it reddens litmus, and has a sweetish but very nauseous taste; it speedily blackens some of the white metals, and all their solutions, particularly lead, silver, and mercury, and precipitates several metals from their solutions; and lastly it combines copiously with the alkaline, earthy, and metallic bases, saturating them like an acid.

This gas is procured in greatest abundance by means of the solid sulphurets, either of the alkalies or of iron, and an acid. For this purpose put some pieces of the sulphuret of potash (for example) made by melting together equal parts of sulphur and common carbonat of potash, into a proof bottle, and add sulphuric or muriatic acid moderately dilute. An effervescence will ensue, attended with an intensely fetid smell, and the sulphuretted hydrogen gas rises in abundance. It may be collected either over water or mercury; if the former, part of it is absorbed by the water; if the latter, the mercury is a good deal blackened at the surface. This gas when obtained from the alkaline sulphuret, unless a caustic alkali be used, is however mixed with carbonic acid, and therefore this sulphuret is not so good a material as the *sub sulphuret* of iron, or that in which the sulphur is in much smaller proportion to the iron than in the common native sulphuret or pyrites. The difference between these sulphurets has already been fully explained under the article IRON, *(Vol. I. p. 623 & seq.)* and a mass very convenient for yielding the gas may be prepared by half-filling a crucible with common iron pyrites, covering it with a third or half its weight of iron filings, over this pressing a little charcoal powder, and heating the whole moderately red-hot for a quarter of an hour. It is not necessary to urge the heat to the fusion of the materials. The pyrites and iron filings may also be previously mixed and treated as above. This gives a black brittle uniform mass that yields abundance of the gas with muriatic or dilute sulphuric acid. A mixture of three parts of iron-filings and one of sulphur simply melted together in a covered crucible, answers as well as the pyrites and iron filings.

Sulphuretted hydrogen when pure is heavier than common air (according to Kirwan) in the proportion of 10000 to 9038, so that 100 cubic inches of it weigh about 33 grains. When

[a] Phil. Trans. for 1786.

[b] Journ. de Physique for 1785.

mixed with its own bulk of common air and kindled, it takes fire and burns with a blue flame without detonation. During the combuſtion ſulphur is conſtantly depoſited, and a ſulphureous ſmell is perceived. When previouſly mixed with oxygen and kindled, it explodes with ſome violence, though leſs in degree than an equal quantity of hydrogen in ſimilar circumſtances. A mixture of equal parts of ſulphuretted hydrogen and nitrous gas burns with a greeniſh-yellow lambent flame, and ſulphur is depoſited. According to Sennebier this gas mixed with common air cannot be kindled by the electric ſpark.

This gas is diſtinguiſhed by the depoſition of all or part of its ſulphur whenever it is decompoſed, whether by combuſtion or acids, or in any other way; for as it conſiſts ſimply of hydrogen holding a quantity of ſulphur in ſolution, and as in all theſe decompoſitions the hydrogen is the ſubſtance firſt acted on by the decompoſing ſubſtances, at the inſtant of decompoſition it quits its ſulphur before the latter has an opportunity of undergoing its peculiar changes. Thus in the combuſtion of this gas with a large portion of common air, the hydrogen unites with part of the oxygen of the air, and produces water, and at the ſame inſtant part of the ſulphur undergoes combuſtion with another portion of the oxygen, and produces ſulphureous acid, as is obvious to the ſmell, but the reſt of the ſulphur is precipitated in its natural form.

Sulphuretted hydrogen is readily abſorbed by water, and in conſiderable quantity. Mr. Kirwan eſtimates that at a moderate temperature water will take up about three fourths of its bulk of the gas as procured from ſulphuret of iron, and by long continued agitation it may be made to abſorb as much as twice its bulk. The whole is again expelled at a boiling heat. Hydro-ſulphuretted water has a ſweetiſh nauſeous taſte, and a very ſtrong fetid ſmell, but the diſguſt excited at firſt taſting it, goes off very ſoon when daily uſed, as it is medicinally. This combination is found native in many ſprings, all the cold ſulphureous mineral waters, ſuch as thoſe of Harrowgate, Moffat, &c. being natural ſolutions of ſulphuretted hydrogen in water. A much ſmaller quantity of the gas than can be artificially condenſed in water is ſufficient to render water moſt powerfully ſulphureous to the taſte and ſmell, for the Harrowgate, which is ſo celebrated, contains no more than about $\frac{1}{12}$ of its bulk of the gas. Hydro-ſulphuretted water if expoſed to the air for a ſhort time grows turbid, and the ſulphur is ſlowly depoſited on the ſides of the veſſel in the form of a thin yellow film. A ſimilar decompoſition takes place, though in a longer time, even when kept in a cloſe veſſel. The water after this loſes its peculiar ſcent. Hence in uſing theſe waters medicinally it is neceſſary to drink them at the ſpring head, or very ſoon after being drawn.

Hydro-ſulphuretted water reddens the infuſion of litmus, which ſeems to ſhew ſome acid property. On adding a few drops of ſulphureous, nitric, or oxymuriatic acid to the water, ſulphur is immediately depoſited, which is the only way of extracting the ſulphur from it in ſubſtance. Theſe acids ſeparate the ſulphur by combining with the hydrogen. But if a great exceſs of oxymuriatic acid is uſed, the ſulphur itſelf becomes oxydated, and converted into ſulphuric acid, ſo that the liquor becomes again tranſparent, and the newly generated ſulphuric acid may be precipitated, and its quantity (and conſequently that of the ſulphur) eſtimated by a barytic ſolution. Hydro-ſulphuretted water does not affect lime-water till after ſtanding for ſome time, and then the precipitate is ſulphur and not lime, and hence is not rediſſolved by weak muriatic or any other acid. This forms a deciſive teſt to diſtinguiſh this gas from carbonic acid or any admixture of the two. This water or any other ſolution of ſulphuretted hydrogen alſo immediately blackens the ſolutions of lead, ſilver, and biſmuth, and produces other peculiar effects on metallic ſalts, which will be preſently mentioned.

The following effects were produced by the mixture of this with the other gaſſes,[c] the experiments being performed *over mercury*.

Equal parts of ſulphuretted hydrogen and common air mixed together remained unaltered for ſeveral days, with a diminution of only $\frac{1}{120}$ in bulk, and a blackening of the ſurface of the mercury. The ſame took place when pure oxygen gas was ſubſtituted to common air, and after eight days the mixture exploded when fired. Very little action therefore takes place between theſe gaſſes unleſs water be preſent.

Equal parts of ſulphuretted hydrogen and muriatic acid gas remained unaltered, and the mercury was not blackened.

No action enſued on mixing this gas with carbonic acid gas.

On adding five cubic inches of ſulphureous acid gas to one of ſulphuretted hydrogen, in leſs than a minute, without agitation, the ſides

c Kirwan.

of the glass were covered with a whitish scum which seemed moist, and a diminution of one cubic inch took place. Six more cubic inches of sulphuretted hydrogen were added successively, a diminution took place after each, so that at last 11 inches, (namely 5 of sulphureous acid gas, and 6 of sulphuretted hydrogen) were reduced to 3 inches, part of which was soluble in water, and the remainder was azot. The jar was coated with sulphur in the process, and when rinced out, the water used for the purpose gave a white precipitate with the solutions of barytes, silver, and lead, and lime-water, and contained both carbonic and sulphuric acids. The colour of the precipitates of the above metallic solutions proved that all the sulphur in the sulphuretted hydrogen had been separated before the water was admitted to the residual gas. The mutual actions that take place between all these substances must be very complicated. On the one hand sulphur dissolved in hydrogen is mixed with a gasseous combination of sulphur not saturated with oxygen, and the products are, much sulphur in substance, water and sulphuric acid, or sulphur *saturated* with oxygen, (the carbonic acid and azot being put out of the question, as being probably accidental impurities) and withal there is a great diminution in the bulk of the gasses. Therefore we must suppose that the hydrogen of the sulphuretted hydrogen unites with part of the oxygen of the sulphureous acid gas to produce water, and thereby deposits in substance the sulphur with which it was combined; and on the other hand the sulphureous acid being deprived of part of its oxygen, deposits much of its sulphur in substance, whilst the remainder of its oxygen condenses itself into another part of the sulphur and produces sulphuric acid. According to this explanation therefore, both the gasses contribute to the formation of the sulphur, and certain it is that the quantity of sulphur is much too great to arise solely from the sulphuretted hydrogen.

When 8 cubic inches of sulphuretted hydrogen were mixed with 9 inches of nitrous gas, a yellowish cloud appeared, together with a sudden absorption, which gradually increased, till after 48 hours the whole was reduced to 6 cubic inches, and the top and sides of the jar were covered with a white cake of sulphur. The residual air appeared to be nitrous oxyd. The theory of this decomposition is obvious, and much simpler than the last, the hydrogen of the sulphuretted hydrogen uniting with part of the oxygen of the nitrous gas, leaving the remainder in the form of nitrous oxyd, and the sulphur being deposited unchanged.

Sulphuretted hydrogen and ammoniacal gas appear to combine totally if the ingredients are pure and in proper proportions. On adding 6 cubic inches of the former to 7 of the latter gas a small white scum appeared, but in a few seconds the whole was reduced to $\frac{4}{7}$ of an inch, and on throwing up water only $\frac{1}{7}$ of an inch remained. The water thus impregnated is a solution of hydro-sulphuret of ammonia, and, as appears, no decomposition takes place, for scarcely any sulphur is deposited. This combination will be afterwards mentioned more at large.

Sulphuric acid absorbs sulphuretted hydrogen. One measure of the acid, of 1.863 sp. gr. was found by Mr. Kirwan to take up nearly 2 measures of the gas over mercury, and the acid was whitened with a copious deposition of sulphur.

Concentrated nitrous acid absorbs part of the air and separates sulphur, but it is extremely difficult to contrive an unexceptionable mode of making the experiment, for the acid acts upon mercury, and if water is used, it dilutes the acid so much that it no longer has the power of decomposing the gas and separating the sulphur.

Alcohol readily absorbs about thrice its bulk of this gas. Water precipitates a part of the sulphur from it. Sulphuric ether also absorbs about half its bulk of the gas.

It has been mentioned that the easiest method of procuring sulphuretted hydrogen, is by adding an acid to the alkaline, earthy, or metallic sulphurets.

In this case, as Gengembre has proved, part of the water of the acid is decomposed, its hydrogen forms a gaseous combination with part of the sulphur present, and produces the sulphuretted hydrogen, whilst its oxygen unites with another portion of sulphur, and forms sulphuric acid, which is always found in the residue in exact proportion to the quantity of gas produced.

Sulphuretted hydrogen is also formed without any apparent decomposition of water, being produced in abundance by heating strongly a mixture of sulphur with any substance that yields hydrogen. Thus Mr. Kirwan obtained it in large quantity by heating a mixture of two parts of white sugar (previously melted to expel all the moisture) with one of sulphur. This gas was very pure and contained neither carbonic nor any other acid. On the other hand a mixture of sugar and sulphur moistened with

muriatic acid gave out no gas, because there was no power applied capable of resolving the sugar into hydrogen. Many other methods of obtaining the gas might be suggested, in which sulphur should be in contact with hydrogen at the moment of its formation. This gas however is not produced by heating sulphur in contact with hydrogen gas, nor by passing this gas over sulphur melted, and kept red-hot in a close tube, so that it appears necessary in all cases that the hydrogen should be presented to the sulphur either in a nascent state, or condensed in a solid or liquid.

According to Mr. Kirwan, 100 cubic inches of this gas contain about 30 grs. of sulphur. Whence, supposing that 100 cubic inches of common air weigh 30.414 grs. (at 60° Th. and 29.5° Bar.) and that this gas is heavier than common air in the proportion of 10000 to 9038, 100 cubic inches of sulphuretted hydrogen should weigh 33.65 grains, of which 30 grains are sulphur, and 3.65 grains hydrogen. The quantity of sulphuretted hydrogen contained in any water, he estimates by the quantity of sulphur precipitated and collected, when a given portion of the water is decomposed by nitrous gas and common air, as will be more fully described under the article WATERS (*Mineral*). In this method therefore, and from the above data, 30 grs. of sulphur would indicate 100 cubic inches of the gas, and therefore one grain of sulphur is equivalent to 3⅓ cubic inches of the gas.

The estimation made by Thenard, of the composition of this gas, does not even approach to that of Kirwan just mentioned. Thenard estimates the cubic centimetre of the gas to weigh (at a medium pressure and temperature) 1.513 millegrammes, which reduced to English measure would give the weight of 100 cubic inches at 41.1 grains instead of 33.65 as Mr. Kirwan estimates it. Mr. Thenard analyses the gas by causing water to absorb the whole, and then adding oxymuriatic acid sufficient first to precipitate the sulphur, and then to convert it totally into sulphuric acid, from the weight of which (as indicated by the quantity of sulphat of barytes formed on adding muriated barytes) he estimates that of the sulphur entering into its composition. From these data he concludes that 100 parts, by weight, of the gas are composed of 70.857 of sulphur, and 29.143 of hydrogen, whereas the proportions given by Mr. Kirwan would be (in 100 by weight) about 89.1 of sulphur, and 10.9 of hydrogen.

Though much of this difference must be ascribed to the different mode of analysis pursued, part of it may doubtless arise from occasional variation in the constitution of the gas, for there is no satisfactory reason for supposing that the degree of sulphuration of this gas should be always uniform, any more than the proportion of phosphorus in the phosphuretted hydrogen, or of arsenic, in the arsenicated hydrogen, which are known to vary considerably.

There is likewise some difference in the sulphuretted hydrogen, according to the sulphuret or other material from which it is procured, independently of any palpable admixture of carbonic acid or other known gasses, for that which is procured from the sulphuret of strontian burns with a *red colour* like the salts of this earth, which would shew that some of the strontian itself is volatilized along with the gas.

Metallic Hydro-sulphurets.

Sulphuretted hydrogen exercises a very strong action on some metals in substance, and on many more metallic salts. When sulphuretted hydrogen, either in the gasseous form, or dissolved in water, is added to a metallic solution, part of the hydrogen first unites with part if not all of the oxygen of the metallic oxyd, and reduces it nearly to the metallic state, and the remainder of the sulphur and hydrogen unite with the metal, and the whole is generally separated from the acid of the solution in the form of a coloured precipitate, which therefore is either a sulphuret or a hydro-sulphuret of the metal according to circumstances. Sometimes too a small portion of sulphuric acid is formed at the same time, which renders the play of affinities still more complex. Some of the metallic solutions afford no precipitate with sulphuretted hydrogen, or at least the precipitate is redissolved by a slight excess of acid, but with other metals it is permanent.

Nitro-muriat of *Gold* is precipitated black by hydro-sulphuretted water,[a] — nitrat of *Silver*, black, but the precipitate is again soluble by agitation if there is a sensible excess of acid—nitrated *Mercury*, yellowish brown, and *Corrosive Sublimate* dark yellow, which becomes black by agitation—sulphat of *Copper*, black, and nitrat of *Copper* brown—nitro-muriat of *Platina*, reddish white—the salts of *Lead*, deep black—those of *Zinc*, white—the salts of *Bismuth*, reddish brown, passing into black—muriat of *Tin*, a dull white.

The metals that are not precipitated from their solutions by sulphuretted hydrogen, are *Iron*, *Cobalt*, *Nickel*, *Manganese*, and in some cases *Antimony* and *Arsenic*. These solutions however are deeply coloured by the sulphuret,

[a] Kirwan and Berthollet.

that of iron becoming black; of antimony, orange; of arsenic, yellow, &c. but either no precipitate forms, or if formed, it is redissolved by any excess of acid. Thus if sulphuretted hydrogen is added to a solution of the red sulphat of iron, the metal is immediately brought to the state of the green, or less oxygenated sulphat, but no precipitate is formed unless the sulphuretted hydrogen be in great excess, as the red sulphat has naturally an excess of acid. On this principle is founded an useful test to distinguish iron from lead in wine or any other liquor, for by adding hydro-sulphuretted water, and a slight excess of dilute muriatic, or any other weak acid, if iron only be present, the liquor will assume a deep red, but will remain transparent, whereas lead will give a black muddy sediment. Often too this test is useful for separating one metal from another in the same solution, both where a precipitable and a non-precipitable metal are present, and where there are metals more or less easily precipitable. Thus if manganese, zinc, tin, and copper, are in the same solution, the first addition of hydro-sulphuretted water will separate the tin, after which the copper will fall, and then the zinc, whilst the manganese remains in solution.

In all the above circumstances it is the simple hydro-sulphuretted water which is meant, and not the alkaline hydro-sulphurets, for though the action of the latter is in general very similar to that of the simple hydro-sulphurets there are some important differences, and in particular, the alkaline hydro-sulphurets precipitate *all* the metallic solutions without exception, as will be afterwards noticed.

Alkaline and Earthy Hydro-Sulphurets.

Sulphuretted hydrogen unites readily, and in large quantity with the alkalies and alkaline earths, forming transparent, colourless, often crystallizable salts, in which the base is nearly if not entirely saturated, and from which the sulphuretted hydrogen is expelled in strong effervescence by the addition of a stronger acid (as the carbonic is from the carbonats) without any other decomposition or deposition of sulphur, unless the acids used are the nitrous or oxymuriatic which are themselves decomposed, and yield oxygen to the sulphuretted hydrogen.

The hydro-sulphurets are all soluble in water, and the solution is at first colourless, but by exposure to air it becomes first greenish yellow and then deposits sulphur, and in this state the stronger acids cause a further precipitation of sulphur. After a while also sulphureous acid is formed, and may be expelled by a stronger acid, but this does not take place till all the sulphuretted hydrogen is decomposed. Finally, when the hydro-sulphuret has been very long exposed to the air it becomes again entirely colourless, and loses all its sulphureous smell and taste, and is converted into a sulphat of the alkali or earth which was originally employed.

Hydro-Sulphuret of Potash is formed by passing sulphuretted hydrogen through a solution of potash till no more will be absorbed, and expelling the excess of sulphuretted hydrogen by boiling for a few minutes. The solution evaporated and crystallized gives a perfectly transparent colourless salt in large crystals, with an alkaline and very bitter taste. It deliquesces in the air, and then has the peculiar fetid smell of sulphuretted hydrogen, but when dry it is scentless. It dissolves in water and alcohol, producing cold during solution, which is a proof of the complete saturation of the alkali. Acids cause a lively effervescence and expell pure sulphuretted hydrogen, but no sulphur is deposited.

This salt may be formed by calcining a mixture of sulphat of potash and charcoal, by which the sulphat is converted into a sulphuret, and by lixiviating the sulphuret with water, and saturating this solution with sulphuretted hydrogen by which the excess of sulphur will be deposited, and a simple hydro-sulphuret of potash will remain in solution.

Hydro-sulphuret of Soda. This salt is prepared in the same manner as the last, and resembles it closely in most of its chemical properties. It was first obtained crystallized by Vauquelin, in the following way; a mass of impure carbonat of soda procured by the decomposition of common salt was lixiviated to extract the carbonat of soda, and the mother liquor after standing at rest for a considerable time was found filled with a colourless transparent salt crystallized in four-sided prisms, which had an acrid burning taste succeeded by an intense bitterness, and a slight flavour of sulphuretted hydrogen. This salt dissolves copiously in water, producing cold during solution, and the liquid has a slightly sulphureous smell. Muriatic and sulphuric acids expell sulphuretted hydrogen, and do not produce any turbidness, but the nitric and oxymuriatic acids, (that is, those which yield oxygen readily) separate an abundance of sulphur.

The mode of its production in the case mentioned by Vauquelin, must have been the following; muriat of soda was decomposed in the large way, (probably by gypsum and pyrites)

and a proportional quantity of fulphat of foda produced; the latter falt was decompofed by the combination of chalk and charcoal (in the way defcribed under the article *Muriat of Soda*, *p.* 130) and a quantity of carbonat of foda was produced, but probably owing to not employing chalk enough, part of the fulphat of foda efcaped entire decompofition, and was converted by the charcoal into a fulphuret, which by lixiviation became a hydro-fulphuret, and cryftallifed by repofe.

Hydro-fulphuret of foda is ufefully employed as a chemical teft to feparate certain metals from mixed folutions of metals and earths, as the alkaline hydro-fulphurets will precipitate the former but not the latter, except thofe of alumine.

Hydro-fulphuret of Ammonia. The compleat condenfation of fulphuretted hydrogen and ammoniacal gas, confined over mercury, has been already mentioned. The refult is hydro-fulphuret of ammonia, which however is formed more conveniently by paffing the gas through liquid ammonia till the latter is faturated. This folution has a greenifh yellow colour, and agrees with the other hydro-fulphurets in the effential quality of giving out fulphuretted hydrogen on the addition of an acid, and of not precipitating any fulphur in the procefs. When the ammonia is in excefs, and the folution concentrated, it conftantly fends forth white fumes when expofed to air, which confift of unfaturated ammoniacal gas holding hydro-fulphuret of ammonia in folution. This fuming property was firft obferved by Boyle, in the liquor prepared by diftilling lime, fal ammoniac, and fulphur, and which will be afterwards defcribed under the head of *Sulphuretted hydro-fulphurets.*

Hydro-fulphuret of Barytes. This falt might doubtlefs be prepared like the other hydro-fulphurets, fimply by faturating barytic water with fulphuretted hydrogen; but it is more conveniently obtained, as Berthollet has difcovered, through the intermedium of the dry fulphuret of barytes. For this purpofe mix fulphat of barytes with about a fixth of its weight of finely powdered charcoal, and calcine it in a moderate red heat for about half an hour, in a covered earthen crucible. This produces a fulphuret of barytes which is to be diffolved to faturation in boiling water, and on hafty evaporation and cooling a copious quantity of irregular cryftals will be formed, which may be feparated from the adhering liquor by preffing them between folds of filtering paper. The falt is then white and tranfparent, and is the hydro-fulphuret of barytes. The folution that remains is the fame falt with an excefs of fulphur. If the firft folution before the feparation of the faline cryftals be decompofed by carbonated foda, carbonat of barytes falls down, and the folution contains very pure hydro-fulphuret of foda. If muriatic acid be added inftead of carbonated foda, a moft copious emiffion of fulphuretted hydrogen takes place, and muriated barytes remains in folution. The above methods of procuring carbonat and muriat of barytes are very ufeful in the laboratory.

Sulphuret of barytes gives out a greater quantity of fulphuretted hydrogen than any other of the fulphurets, whence the eafe with which that portion of the earth becomes faturated with the fulphuretted hydrogen, which feparates in the cryftalline form. This is explained by Berthollet from the ftrong affinity which barytes has with fulphuric acid, and the confequent rapidity with which this acid is generated. Hydro-fulphuret of barytes has an acrid and fulphureous tafte, and is readily decompofed by the atmofphere, and fulphat of barytes is precipitated along with fulphur.

Hydro-fulphuret of Strontian. This falt is formed precifely in the fame way as the former. The gas which it gives out when decompofed by acids burns with a red flame like the other falts of ftrontian.

Hydro-fulphuret of Magnefia. If pure magnefia is diffufed through water, and fulphuretted hydrogen paffed through, a folution is effected, and a hydro-fulphuret of magnefia is formed.

Hydro-fulphuret of Lime. This falt is obtained by paffing fulphuretted hydrogen through lime diffufed in water. A ftrong yellow folution is made which, when poured off clear from the remaining lime, fhould be fully faturated with the gas, and the excefs, if any, afterwards expelled by boiling. This folution has not been cryftallized.

Berthollet, to whom we are indebted for the moft accurate ideas and experiments on the hydro-fulphurets, affigns to barytes the firft rank in the order of affinities of the refpective alkaline and earthy bafes to fulphuretted hydrogen. As potafh precipitates lime from the hydro-fulphuret of lime, it precedes lime in affinity, and lime precipitates and decompofes the hydro-fulphurets of ammonia and magnefia. The order of affinity therefore is, probably, barytes, ftrontian, potafh, foda, lime, ammonia, and magnefia, the two latter nearly equally. When an alkaline hydro-fulphuret is added to any earthy falt, (thofe of alumine and zircon excepted) no preci-

pitation takes place, either becauſe no decompoſition occurs, or becauſe the new compounds are equally ſoluble with the former. The ſolutions of alumine and zircon, however, are precipitated by the alkaline hydro-ſulphurets, as well as all the metallic ſalts.

The action of the alkaline hydro-ſulphurets on metallic ſalts will be afterwards mentioned.

SULPHURETS OR HEPARS, *Liver of Sulphur. Sulfure* of Berthollet, and other French chemiſts.

When ſulphur is melted with an alkali a brown uniform maſs is produced, which as long as it continues dry is a ſimple combination of ſulphur and alkali. But while diſſolving in water a certain quantity of ſulphuretted hydrogen is immediately generated, which remains in the ſolution and unites with the ſulphur and alkali, but may be expelled by the addition of an acid, which at the ſame time precipitates the greater part of the ſulphur in a ſtate of purity. The liquid ſulphurets therefore contain ſulphur, alkali or alkaline earth, and ſulphuretted hydrogen, ſo that they differ from the hydro-ſulphurets of the ſame baſes in containing a large exceſs of ſulphur, and therefore give with acids a copious precipitate of ſulphur, which the ſimple hydro-ſulphurets do not.

Berthollet conſiders the ſulphuretted hydrogen in the liquid alkaline ſulphurets as the intermede by which the ſulphur is diſſolved in the alkali, and therefore as an eſſential part of the compound, and he denies the poſſibility of a liquid ſulphuret exiſting without containing ſulphuretted hydrogen in its compoſition. Hence he terms theſe compounds *Sulfures Hydrogenés*, which Mr. Chenevix calls *Hydroguretted Sulphurets*, and which may with equal propriety be termed *Sulphuretted Hydro-ſulphurets*.

But it is not every combination of ſulphur, ſulphuretted hydrogen, and a baſe, to which this term can, as we apprehend, be juſtly given, but only to that compound in which the whole of the ſulphur may be ſuppoſed to be united entirely with the ſulphuretted hydrogen, and through its intervention, to the baſe; or in other words, to a compound in which no further addition of ſulphuretted hydrogen will cauſe a precipitation of ſulphur. For the common liquid ſulphurets (made either by uniting ſulphur to an alkali by fuſion, and diſſolving the melted maſs, or by boiling the alkaline ſolution with ſulphur) contain a very large exceſs of ſulphur, moſt of which is ſeparated by every acid, and alſo a great part of it by ſulphuretted hydrogen, which here as in many other inſtances performs the part of an acid, and uniting to the alkali with a ſtronger affinity than ſulphur does, expells part of it, but alſo diſſolves another portion, and carries this latter along with it into the compound which it then forms. The proper ſulphuretted hydro-ſulphurets therefore are thoſe which are made by digeſting a hydro-ſulphuret with ſulphur, which, as Berthollet has ſhewn, takes up a portion of it, and again depoſits it on the addition of a ſtronger acid. Perhaps too the hydro-ſulphurets when they have been ſo long expoſed to the air as to turn yellow and depoſit ſulphur by the addition of an acid, may be conſidered as ſulphuretted hydro-ſulphurets, though in a much leſs concentrated ſtate than the former.

With regard to the common liquid ſulphurets, Prouſt has alſo ſhewn that the proportion of ſulphuretted hydrogen which they contain, varies ſo much, and is ſo little proportioned to the quantity of ſulphur actually preſent in the ſolution, as to render it extremely improbable that the whole, or even the greater part of the ſulphur is united to the alkali in ſolution by the intervention of the ſulphuretted hydrogen which they all confeſſedly contain.

The ſame excellent chemiſt has alſo given a method (which we ſhall preſently mention) by which every ſenſible portion of ſulphuretted hydrogen may be extracted from the ſolution; whilſt the alkaline baſe and the greater part of the ſulphur remain untouched,—another preſumptive proof that ſulphuretted hydrogen is not eſſential to the liquid ſolution of ſulphur in alkali.

We ſhall therefore retain the terms *dry* and *liquid ſulphuret*, to ſignify the common ſolid and fluid combinations of ſulphur with a baſe, and proceed to deſcribe the individual ſulphurets.

Sulphuret of Potaſh. Common Liver of Sulphur. The combination of ſulphur and potaſh is that which has been the longeſt known to chemiſts, and may be prepared in ſeveral ways. The antient method is the following: mix two parts of dry carbonat of potaſh with one of ſulphur and melt the mixture in a crucible with a heat gradually raiſed to redneſs, till the whole flows into an uniform maſs. As the potaſh is carbonated, a conſiderable efferveſcence ariſes when the materials begin to melt; ſo that the crucible ſhould be large and the heat gradual. When the ſwelling of the maſs has ſubſided and the whole remains in quiet fuſion, pour it out on a ſmooth greaſed ſtone, and as ſoon as it is cool enough to be handled, break it and put the

excess in the solution, and is dissolved in the pieces into a well closed dry bottle. The sulphuret thus prepared is a hard, brittle, shining, heavy mass, somewhat vitreous in its fracture, and of a deep brown or *liver* colour, whence the antient name of liver of sulphur. As long as it remains dry it is without smell. On laying a minute portion on the tongue it tastes excessively sharp, burning and bitter, along with the peculiar nauseous flavour of sulphuretted hydrogen. When the solid sulphuret is exposed to the air it first turns green, which passes to grey, it also absorbs moisture pretty rapidly, and then begins to exhale the odour of sulphuretted hydrogen, but it does not actually deliquesce as melted potash alone does. When moist, it stains the skin of a yellowish brown which is difficult to remove.

This sulphuret however is not entirely pure, for being made with a carbonated alkali it retains some carbonic acid, though much of it escapes during the fusion, and hence on the affusion of an acid, carbonic acid gas rises in mixture with the sulphuretted hydrogen. The pure dry sulphuret must therefore be made with dry caustic potash, melted with about its own weight of sulphur. The mixture in this case enters into fusion, and the union is compleat before it reaches a red heat.

When caustic potash and sulphur are rubbed together in a mortar they unite rapidly, the mixture grows hot, and soon is converted into a yellowish green mass which exhales a fetid smell. In this case the moisture which the alkali absorbs from the air assists the combination.

A solid sulphuret of potash may also be formed by mixing dry sulphat of potash with about a sixth of its weight of charcoal, and melting the mixture in a red heat for a considerable time. In this case the sulphuric acid is decomposed by the charcoal with much intumescence, and the sulphur resulting from the decomposition unites with the alkali, and the whole forms a dark brown sulphuret. This however is much less pure than the sulphuret made by direct combination, for besides any undecomposed sulphat which it may contain, it holds in solution a quantity of charcoal. Charcoal therefore is soluble in a red heat in this sulphuret. When the dry solid sulphuret is urged with a violent and long continued heat, the sulphur is again driven out, along with part of the carbonic acid if a carbonated potash had been used, and alkali alone remains. If a dry fixed acid such as the phosphoric or boracic be mixed with the sulphuret and heated, the sulphur is expelled more easily, and the acid and potash remain behind. In all these processes no sulphuretted hydrogen is given out provided the sulphuret and other substances be quite free from moisture.

Liquid sulphuret of potash is made either by dissolving any of the dry sulphurets in water, which is done with the utmost ease, or by dissolving sulphur directly in a solution of caustic potash with a boiling heat. It is then a yellow fetid liquor, excessively acrid and caustic if concentrated, changing vegetable colours like the alkalies; and also, like these, corroding animal and vegetable matter. It dissolves many metals with rapidity, bringing them to the state of a sulphuret. When kept for a time even in close vessels it deposits sulphur.

The liquid sulphuret is well known for the facility with which it abstracts oxygen from common air or any mixture of oxygen, and hence its use in *Eudiometry*, as has been fully explained under that article.

When the liquid sulphuret is made with perfectly caustic alkali, it gives out no sulphuretted hydrogen by heat, at least not in a heat of boiling water, but when made with carbonated alkali a considerable quantity of gas is given out which however is chiefly carbonic acid. This sulphuret is also soluble with ease in alcohol.

When muriatic or any other acid is added to solid sulphuret of potash, there is a copious disengagement of sulphuretted hydrogen) mixed with carbonic acid, if a carbonated alkali had been employed) and a large quantity of sulphur is precipitated. The liquid sulphuret also gives out with an acid a large quantity of the gas or gasses, and the mixture becomes immediately turbid and thick by the abundant precipitation of sulphur. The latter when washed and dried is very pure sulphur of a white or cream colour, and is called *Milk* or *Magistery of sulphur*, or *Precipitated sulphur*.

The action of mercury and its oxyds on the liquid sulphurets and hydrosulphurets has been urged with great ingenuity by Proust,* in explanation of the nature of these compounds. Running mercury agitated with the pure colourless hydrosulphurets is not changed in any degree, so that this metal cannot take sulphur from hydrogen when they are in perfect saturation and united with an alkaline or earthy base. But when the hydrosulphuret has begun to become yellow by short exposure to air, that is to say, when by an oxydation of part of the hydrogen the sulphur which was united to it becomes in

* Journ. de Phys. tom. 59. p. 267.

remaining sulphuretted hydrogen, the mercury extracts from the solution this excess of sulphur, (immediately, from the hydro-sulphuret of ammonia, and in a short time, from the other hydrosulphurets) and the liquid returns to the state of simple hydro-sulphuret. A portion of the sulphuretted mercury remains dissolved, whilst the solution is concentrated, but on diluting with water or alcohol it becomes turbid, and black sulphuret of mercury is precipitated, and the liquor is again restored to the state of simple hydrosulphuret of the alkali employed. If however the excess of sulphur is so great as to bring the mercury at once to the state of red sulphuret none of it is dissolved, though the same change takes place in the liquor. Mercury therefore in *the metallic state* analyzes all these compounds of sulphur, sulphuretted hydrogen and alkali, by extracting all the sulphur except that portion which is saturated with hydrogen, and in the state of sulphuretted hydrogen; and hence it almost entirely extracts the sulphur from those liquid sulphurets which scarcely effervesce with acids, and contain but a minute portion of sulphuretted hydrogen, and reduces them almost to the state of simple alkaline solutions.

But on the other hand a precisely opposite effect takes place when the *red oxyd of mercury* is used, for when this is agitated with a hydro-sulphuretted alkali, its first action is to decompose all the sulphuretted hydrogen which it contains, which is attended with a sensible evolution of heat; and if no more oxyd be used than is necessary to engage the hydrogen, the remaining liquor becomes yellow, but remains clear after the subsidence of the oxyd, and is a simple liquid sulphuret, from which muriatic acid precipitates sulphur, but without the evolution of a particle of sulphuretted hydrogen. If an additional quantity of red oxyd be added, the sulphur is precipitated in combination with the metal, and the supernatant liquor is then little else than a solution of potash, holding a little oxyd of mercury, and sometimes sulphite of potash. A similar change takes place with the common liquid sulphuret of potash, which, as already mentioned, consists of sulphur, potash, and hydrosulphuret of potash. The first portion of oxyd engages the hydrogen of the hydrosulphuret, and detaches the sulphur belonging to it, which dissolves in the sulphuret that remains in solution, and by destroying the hydrogen, takes from the solution of the property of effervescing with an acid. The oxyd also loses oxygen, which unites with the hydrogen, and the metal absorbs a portion of sulphur and becomes black sulphuret, part of which remains in solution. This first change takes place without any effervescence, and with disengagement of sensible heat. But on adding a fresh portion of oxyd the heat is renewed, an effervescence occurs owing to the escape of part of the oxygen of the oxyd, the mercury becomes saturated with sulphur and precipitates, and the remainder of the oxygen acidifies the sulphur, and sulphite of potash is found in solution.

The principal point established by this excellent chemist in these experiments, is the possibility of subtracting all the sulphuretted hydrogen from a liquid sulphuret (at least to that degree as to render it non-effervescent with an acid) whilst the alkali and sulphur alone remain in solution; and hence as the possibility of a simple liquid sulphuretted alkali is established, it may fairly be inferred that sulphuretted hydrogen is not the principal intermede by which sulphur and potash are held in liquid combination in the common solutions of the sulphurets.

Sulphuret of Soda. This combination may be made either dry or liquid, by all the methods in which the sulphuret of potash is produced, and it has the same general chemical properties which have been described as belonging to the sulphuret of potash.

Sulphuret of Lime. Lime being infusible *per se*, the combination between lime and sulphur can scarcely, if at all, be made in the dry way; but a liquid sulphuret of lime is readily formed by boiling together sulphur, lime, and water. The proportions are of not much consequence: the following answer very well: put into a glass mattrass three ounces of well-burnt lime, one ounce of sulphur, and about a quart of distilled water. The sulphur should first be rubbed with a little of the water, that it may mix uniformly, and the lime should be broken down. Bring the liquor to a boiling heat, and continue it for half an hour or an hour, shaking it frequently during the time. The liquor soon becomes clear by subsidence as soon as removed from the fire, and a fine yellow strong solution of sulphuret of lime may be poured off clear from the settlings, which should be kept in a well closed bottle.

Though sulphur is absolutely insoluble in water, and lime very sparingly soluble, the sulphuret is considerably so, and when much concentrated when hot, part of it separates by cooling into crystals not easily resoluble in the

liquid, which are probably ſimple hydro-ſulphuret of lime.

When liquid ſulphuret of lime is expoſed to the air, it abſorbs oxygen pretty rapidly (as all the liquid ſulphurets do), and the ſulphur changes to ſulphuric acid; ſo that the ſurface of the liquor is ſoon covered with a hard cruſt of ſulphat of lime, which prevents the fluid beneath from being acted on in the ſame manner, unleſs the cruſt is broken by ſhaking. This ſalt has been propoſed to be uſed inſtead of the alkalies in bleaching, as all the ſulphurets poſſeſs highly detergent qualities, and this can be prepared much cheaper than the alkaline ſulphurets. Mr. William Higgins, of Dublin, the inventor, gives the following proportions:[a]—boil in an iron kettle, for half an hour, 4lbs. of ſulphur, 20lbs. of lime, well ſlacked and ſifted, and 16 gallons of water, with frequent ſtirring. This yields, after a ſhort ſubſidence, a clear ſulphuret of the colour of ſmall beer, and the ſame quantity of freſh water may be poured on the reſidue to extract the remaining ſulphuret. For the purpoſe of bleaching, the whole quantity of liquid is to be made up to ſixty gallons, and in this brown linen cloth may be ſteeped for twelve or eighteen hours, alternating with oxymuriat of lime, for about ſix times, by which it will acquire the requiſite whiteneſs. The cold liquor anſwers nearly, if not entirely, as well as the hot.

Sulphuret of Barytes and Strontian. The liquid ſulphurets of theſe earths may be made either by boiling the pure earth with ſulphur and water, or by calcining the ſulphats of theſe earths with charcoal, to convert them into ſulphurets, and diſſolving the latter out from any remaining undecompoſed ſulphat. It has been already mentioned, under the head of *Hydroſulphuret*, that theſe ſolutions, when fully ſaturated, depoſit cryſtals which are pure hydroſulphurets, ſince they effervеſce ſtrongly with an acid, and do not depoſit ſulphur in the proceſs. But the entire ſolution contains an exceſs of ſulphur, which will ſeparate on adding an acid.

Sulphuret of Ammonia. Though *ſulphuretted-hydrogen* and ammoniacal gas, will combine in the dry way into a hydro-ſulphuret of ammonia, *ſulphur* cannot be united with this alkali except in the liquid form, and this too is not readily effected, except through the medium of diſtillation; for when ſulphur and liquid ammonia are ſimply digeſted together, it requires a conſiderable time before any ſolution of the ſulphur is obtained.

The liquid ſulphuret of ammonia produced by diſtillation, appears to have been firſt noticed by Boyle, who obſerved its fuming property when expoſed to air, whence it was called *Boyle's Fuming Liquor, or Volatile Liver of Sulphur*. The proceſs as given by Beaumé, ſomewhat improved, is the following: mix together in a mortar, and put into a retort, 3lbs. of ſlacked lime, 1lb. of ſal-ammoniac, 8 oz. of flowers of ſulphur; and add to this, when in the retort, 6 oz. of water. Adapt a tubulated receiver, and proceed to diſtillation with a gentle heat. The firſt drops that condenſe are nearly watery, but thoſe that follow are yellow; and when about 6 oz. of liquor has diſtilled over, a vaſt quantity of white elaſtic vapour ariſes, which fills the receiver, and would burſt it, if it had not vent, and of which only a portion can be condenſed, and with great difficulty. The fire is then to be kept up ſteadily for an hour or more, till the bottom of the retort becomes ſlightly red, during which about ſix or eight ounces more of liquid are obtained.

The product of this diſtillation is a yellow, pungent liquid, ſmelling ſtrongly both of ammonia, and of ſulphuretted hydrogen, and giving out abundance of white fumes the moment it is uncorked. It is the liquid ſulphuret of ammonia. In this proceſs the ammonia, expelled from the ſal-ammoniac by means of the lime, acts upon the ſulphur in the moment of its formation, diſſolves the ſulphur, and, together with the water preſent, riſes in vapour, and condenſes in the receiver. Though only ſix ounces of water are added to the mixture, full double the quantity is obtained, the reſt being expelled from the ſlacked lime by the heat. If leſs water is added, the product is ſtill more fuming, and there is a ſtill greater waſte of incoercible vapour. This waſte, however, was only incurred before the invention of Woulfe's apparatus; for by its adoption the whole of the vapour may be condenſed, either in water, or in an alkaline ſolution, at pleaſure.

To aſcertain the preciſe nature of this fuming ſulphuret, Berthollet made the following experiments: the materials for producing it, namely, lime, ſulphur, and ſal-ammoniac, were mixed in a retort, and the product condenſed as uſual; but was received in two ſeparate portions, the firſt of which was of a light yellow,

[a] Phil. Journal, Vol. 3.

and highly fuming; the second was of a much deeper colour, and not fuming. These were put into separate vessels, and into a third was poured some liquid hydro-sulphuret of ammonia, made by saturating liquid ammonia with sulphuretted hydrogen gas, and which did not fume. Muriatic acid was then added to each; and with the first, namely, that containing the fuming part of the distilled liquid sulphuret, gave but little sulphuretted hydrogen, and caused but little sulphur to precipitate, though a considerable quantity of the acid was required to saturate it: with the second, namely that containing the portion of the distilled liquid which gave no fumes, more effervescence was excited, more sulphuretted hydrogen was evolved, and more sulphur was precipitated: with the third, namely that containing the simple hydro-sulphuret of ammonia, much of the gas was given out, but little or no sulphur was deposited. Other portions of the second and third solutions were taken, and liquid ammonia was added to each, which immediately gave them both the fuming property, and rendered the second liquor in every respect similar to the first.

It therefore appears that the property of sending forth white fumes may exist both in the liquid sulphuret and in the simple hydro-sulphuret, and is produced by an excess of ammonia, which not finding sufficient sulphur or sulphuretted hydrogen to keep it down, is volatilized in the air, and carries with it part of the sulphuretted hydrogen contained in the solution. Hence too, when the fuming hydro-sulphuret is digested with sulphur, it dissolves a portion, and then loses its fuming property, as the excess of ammonia is then engaged by the sulphur. This latter compound (that is, hydro-sulphuret of ammonia, digested with sulphur to saturation) has a deep colour and an oily consistence, and does not deposit sulphur by any further addition of sulphuretted hydrogen; and therefore it is strictly a *sulphuretted hydro-sulphuret*, or *hydroguretted sulphuret*, in the sense to which we have limited it in the beginning of this article; and an excess of ammonia would convert it into a compound exactly the same as the fuming sulphuret described by Boyle. The latter soon loses its fuming property on exposure to air, after which it absorbs oxygen like the other sulphurets, and a white sulphur is deposited.

SUPER-SULPHURETTED SULPHUR. *Hydroguretted Sulphur of* Chenevix, *Soufre Hydrogené.* This is a very curious combination, discovered by Berthollet, and consists simply of sulphuretted hydrogen, with a large excess of sulphur, and without any alkaline or other base. It is prepared by mixing at once a large proportion of muriatic acid with liquid sulphuret of potash, or better, by pouring the sulphuret in small portions into the acid, during which most of the sulphur is precipitated as usual, but very little effervescence takes place, and the sulphuretted hydrogen, instead of escaping in a gaseous form, unites with a portion of the sulphur, and condenses with it into a liquid of the appearance of oil, which gradually collects at the bottom of the vessel in which the mixture is made. This substance was first noticed by Scheele.

When this super-sulphuretted hydrogen is mixed with liquid sulphuret of potash, sulphur is deposited; for, as has been already mentioned, the liquid sulphuret is capable of combining with, and actually absorbs from the new compound, an additional portion of sulphuretted hydrogen, which in consequence abandons its excess of sulphur. Another portion of the precipitated sulphur is also furnished by the liquid sulphuret during its further saturation with sulphuretted hydrogen, which in this respect acts as an acid, as has been before noticed. As therefore the portion of sulphur which is already united with an alkali is able to abstract sulphuretted hydrogen from its combination with sulphur alone, it is obvious that the super-sulphuretted hydrogen cannot be produced till there is a sufficient excess of acid to engage all the alkali, and detach it from the sulphur, which happens when a little of the liquid sulphuret is poured into a larger quantity of acid. The suddenness of the decomposition, and density of the fluid produced by the copious deposition of sulphur, appear also to assist in forming this singular compound.

Super-sulphuretted hydrogen may be considered as a compound in which the elasticity of the gas is kept down rather than entirely subdued, by the solid with which it is condensed into chemical union, so that this union is very slight, and is readily broken in circumstances at all favourable to the gas resuming its elasticity. Hence when it is kept in a phial with water, on the surface of which it swims, it is constantly in a state of ebullition, and if the phial is uncorked, the whole of the sulphuretted hydrogen exhales, and the sulphur returns to its original state, and falls to the bottom of the water.[e] Also if a little of this liquid be taken in the mouth, it gives a pungent, bitter,

[e] Proust.

hydro-sulphureous taste which soon goes off, leaving nothing in the mouth but solid sulphur, sticking to the teeth.

When a solution of potash is added to super-sulphuretted hydrogen, a small portion of sulphuretted hydrogen exhales, and the remainder unites with the potash forming a solution which resembles in every respect the common liquid sulphuret of potash.

As the foregoing subject is somewhat intricate, it may be useful to recapitulate shortly, the various combinations of sulphur, hydrogen, and an alkaline or earthy basis, with their distinguishing characters.

1. *Sulphuretted Hydrogen*, a gas somewhat heavier than common air, composed of hydrogen holding sulphur in solution; has a peculiar fetid smell, is inflammable, is absorbed by water, does not render lime-water immediately turbid, when in liquid solution is readily decomposed by exposure to air, or by the acids which easily part with their oxygen, such as the nitrous and oxymuriatic, during which its hydrogen is first engaged and quits the sulphur, which therefore is precipitated in its natural form. Sulphuretted hydrogen reddens litmus, unites largely with alkaline and earthy bases, forming with most of them crystallizable salts in which the base is nearly if not entirely neutralized, separates sulphur from its combination with alkalies, and in all these respects performs the function of an acid. It is however detached from its combinations by every acid, and then re-assumes its gasseous form, and passes off by effervescence. It blackens the solutions of many metals, and precipitates most of them, but not the salts of iron and manganese.

2. *Hydro-sulphurets* are the saline combinations of sulphuretted hydrogen, with the several alkaline or earthy bases. They are, when recently made, perfectly clear and colourless, and on the affusion of a strong acid they effervesce, and give out abundance of sulphuretted hydrogen, but no sulphur is precipitated, the hydrogen being sufficient to carry off the whole of it. The sulphur therefore is solely that which belongs to the constitution of sulphuretted hydrogen. The hydro-sulphurets by exposure to air, absorb its oxygen, and in so doing lose a proportionate quantity of their hydrogen, whereby they turn yellow and cloudy, and on the affusion of an acid they then both effervesce; and deposit sulphur, so that in this state the sulphur is in excess relatively to the quantity of sulphuretted hydrogen.

3. *Sulphuretted Hydro-sulphurets* are hydro-sulphurets holding an excess of sulphur in solution, and are made either by digesting the pure hydro-sulphurets with sulphur, or by exposing them to the atmosphere for a short time, till they turn yellow, and till a portion of the hydrogen is destroyed. The former method however gives the most concentrated solution. These compounds on the affusion of muriatic acid both effervesce and deposit sulphur, but on passing a fresh portion of sulphuretted hydrogen through them, no sulphur is separated, and in this last circumstance they differ from the common liquid sulphurets.

4. *Super-sulphuretted Hydrogen* is that singular liquid produced by decomposing a liquid sulphuret by a large quantity of acid, and consists of sulphuretted hydrogen excessively loaded with sulphur, and adhering to it so loosely as totally to quit it on applying a gentle heat, or exposure to air. An alkaline base therefore is a necessary intermede to effect a permanent union between sulphur and sulphuretted hydrogen, and hence the addition of an alkali to this super-sulphuretted hydrogen, brings it to the state of sulphuretted hydro-sulphuret.

5. *Dry Sulphurets* or *Hepars*. These are simple combinations of sulphur and alkali effected by fusion at a low red heat. When the alkali is carbonated a part of the carbonic acid remains in union, and is expelled by an acid. The dry sulphurets of the alkaline earths can only be made by decomposing their sulphats by fusion with charcoal, and then are impure.

6. *Liquid Sulphurets*. The solution of any dry sulphuret in a watery liquid, or of sulphur in a liquid alkali or alkaline earth, generates a quantity of sulphuretted hydrogen (though in no degree proportionate to the sulphur dissolved) which mixes with the other constituents and the whole forms a caustic yellow liquid with strong alkaline properties. It is composed therefore of the same materials as the sulphuretted hydro-sulphurets, that is to say, of sulphuretted hydrogen, sulphur, and an alkaline base, but differs from these salts in containing a much larger excess of sulphur, and a much smaller quantity of sulphuretted hydrogen, and hence the affusion of an acid causes in general only a small effervescence (sometimes hardly perceptible) but a copious separation of sulphur; and besides (which is a distinguishing mark) much sulphur is precipitated by passing through it a current of sulphuretted hydrogen.

In the liquid sulphurets therefore the sulphur seems to be held in solution by the alkali alone,

and the sulphuretted hydrogen to be but an accessary ingredient; whereas in the sulphuretted hydro-sulphurets the sulphuretted hydrogen appears the principal solvent of the sulphur, and the alkali to act as it were, as an intermede to render this union more permanent.

7. *Simple Liquid Sulphurets.* On the authority of Proust whose experiments have been already detailed, we may admit the existence of a simple liquid solution of sulphur in alkali when the sulphuretted hydrogen has been withdrawn by adding red oxyd of mercury. This liquid deposits sulphur copiously on adding acids, but does not effervesce, and gives out no sulphuretted hydrogen.

8. *Fuming Ammoniacal Hydro-sulphurets and Liquid Sulphurets.* The liquid combinations of sulphur or sulphuretted hydrogen, or both together, with ammonia, have the property of emitting white fumes when the alkali is in excess, which therefore must be considered as another species of this class of substances.

Sulphur unites directly with all the metals except gold and zinc. Chemists have distinguished the different combinations of sulphur with the metal, sulphur with the metallic oxyd, and sulphuretted hydrogen with the metallic oxyd, with or without an excess of sulphur. Of these combinations the simple sulphuret, or union of sulphur with the reguline metal is by far the most intimate, and it is even doubtful if there can be a proper sulphuretted oxyd in the dry state. For if sulphur is mixed with a metallic oxyd and heated in a close vessel to the perfect fusion of the mixture, a quantity of sulphurous acid is always first given out, owing to a deoxydation of the oxyd by a portion of the sulphur, and the metal (nearly if not entirely in a reguline state) remains in permanent union with the remainder of the sulphur. This important fact has been clearly illustrated by the experiments of Proust[i] on the oxyds and sulphurets of antimony. If 100 parts of antimony be distilled with as much sulphur, all the excess of the latter flies off, and there remains at last 135 parts of sulphuret, which continues permanent at a heat more than sufficient to volatilize sulphur alone. If on the other hand a quantity of oxyd of antimony equivalent to 100 parts of the metal, be distilled with as much sulphur, a large quantity of sulphurous acid flies off along with the excess of sulphur, and the residue is as before 135 parts of sulphuret. The other metallic oxyds appear to act in a similar way, whence we may infer it as a general rule that in all the dry combinations of a metal and sulphur, after the utmost effect of exposure to a heat capable of subliming sulphur has been given, the metal is nearly if not entirely reguline, provided there has been sulphur enough added to engage all the oxygen which the metal may have contained.

When metallic solutions are decomposed by the liquid alkaline sulphurets, the metal combines with the sulphur, and a part, at least, of the sulphuretted hydrogen is destroyed, its hydrogen uniting with the oxyd of the solution to bring it to the metallic state, and its sulphur mixing with the other sulphur of the sulphuret. Hence most of the precipitates formed in such cases are simple sulphurets, and not hydro-sulphuretted oxyds. It is even doubtful if there can be a hydro-sulphuretted oxyd, for the first action of sulphuretted hydrogen is to reduce the oxyd to the metallic state, unless instead of a compleat reduction, it brings it to the state of lowest oxygenation. The production of sulphuretted hydrogen by the affusion of an acid on the precipitate formed in such cases is not a satisfactory proof of its being a hydro-sulphuret, as it is with the alkaline and earthy hydro-sulphurets, for with the metallic compounds, the sulphuretted hydrogen may be *generated* by the action of the acid, instead of being merely *evolved*. This is obvious from the usual way of producing this gas by muriatic acid and sulphuret of iron, which therefore throws much difficulty in the way of the analysis of these metallic compounds. It also appears from this that there cannot be a simple metallic hydro-sulphuret, but that this compound whenever it is formed must always exist with excess of sulphur, for there is no other method of producing a hydro-sulphuret than by adding liquid sulphuretted hydrogen, or an alkaline or earthy hydrosulphuret to a metallic solution, and as already mentioned a part of the sulphuretted hydrogen must be decomposed, and an excess of sulphur produced before any combination can take place. The whole of this subject however is still involved in many difficulties, and requires further experiments.

SULPHURIC ACID, Vitriolic acid, Oil of Vitriol. *Acide sulfurique,* Fr. *Schwefelsaure,* Germ.

This acid, perhaps the most important of any for its extensive use, is said to have been found by Baldassari in a concrete state, lining a

[i] Journ. de Phys. tom. 55.

grotto in Mount St. Amiato in Tuſcany; it alſo occurs in the crevices of volcanic mountains, and diſſolved in a few mineral waters. It is not however from any of theſe ſources that the ſulphuric acid of commerce is obtained, the whole of this being procured either from the diſtillation of ſulphat of iron, or from the combuſtion of ſulphur.

Sulphat of iron (or green vitriol) as we have elſewhere ſhown, conſiſts of ſulphuric acid, water, and oxyd of iron; by proper methods the acid may be ſeparated from the other ingredients of the ſalt; and this continued to be the only origin of ſulphuric acid in the great way, till the diſcovery, by the manufacturing Engliſh chemiſts, of the art of preparing it by the combuſtion of ſulphur. As this latter diſcovery has not however as yet entirely ſuperſeded the former, we ſhall give an account of both, beginning with the moſt ancient.

Sulphuric acid is thus prepared at Bleyl, in Bohemia.[a] A long horizontal furnace or gallery of brick-work is conſtructed capable of receiving a number of retorts; the retorts themſelves are pear-ſhaped veſſels, with a ſlightly curved neck, by which they fit into earthen receivers nearly of the form of common retorts. The whole apparatus being prepared, each retort is charged with 3 lbs. of ſulphat of iron, previouſly calcined at a full red heat, and the fire is lighted. The firſt effect of the heat is to drive off the moiſture abſorbed by the vitriol in the interval between its calcination and diſtillation; this phlegm being only very ſlightly acidulous is allowed to eſcape, and when it ceaſes to come over, the receiver with a little water in it is luted on to the retort; the fire is now raiſed and kept up briſk for 32 hours, during which time the acid riſes in the form of denſe white vapours, which fill the receiver, and are there abſorbed by the water. Theſe vapours being at a high temperature ſoon render the receiver very hot, hence the workmen judge of the termination of the proceſs by the receiver becoming cool in conſequence of the vapour ceaſing to riſe. The red oxyd of iron or colcothar, is now taken out of the retort and its place is ſupplied with a freſh charge of calcined vitriol; the diſtillation then takes place as already deſcribed, except that the former produce of acid is not emptied out of the receiver, and therefore there is no occaſion to add any water. If the retort is well made and carefully luted all over, it will laſt for three ſucceſſive diſtillations, and the quantity of acid obtained is nearly equal to half the weight of the calcined ſulphat.

If the acid be examined at different periods of the diſtillation, it will be found to be more and more denſe according to the violence of the fire required for its extrication; the latter portion if received in a ſeparate veſſel will generally congeal upon cooling, hence it is called *glacial ſulphuric acid;* this property however is not entirely owing to its denſity, as we ſhall preſently ſhow.

The ſulphats of copper and zinc have occaſionally been employed, inſtead of the ſulphat of iron, but with a manifeſt diſadvantage, both becauſe they are dearer than the latter ſalt, and becauſe they require a higher and longer continued heat to drive off the whole of the acid.

The following is the uſual method of manufacturing ſulphuric acid from the combuſtion of ſulphur. A chamber is conſtructed of frame work, and lined with ſtrong ſheet lead; the only aperture is a ſmall door, made to ſhut very cloſe, the bottom of which is a little higher than the floor of the chamber. Water is poured into this chamber till it riſes to the heighth of an inch or two upon the floor, and a ſtand is introduced on which is placed an earthen pot containing a few pounds of ſulphur and nitre, in the proportion of from eight to ten of the former to one of the latter; this mixture is ſet fire to by means of a red hot iron, and the door is immediately cloſed; at the expiration of about ſix hours a ſecond charge of ſulphur and nitre is introduced, which after a ſimilar interval is replaced by a third, and ſo on without intermiſſion for a fortnight or three weeks. At the end of this period the water in the chamber is ſufficiently acidulated; it is accordingly transferred to a leaden boiler, where the greater part of the water is evaporated; in proportion however as the acid becomes more concentrated, it is more diſpoſed to corrode and diſſolve the lead of the boiler; therefore before this degree of concentration takes place, the liquor is transferred into large green glaſs retorts, where a degree of heat is applied ſufficient to drive off almoſt the whole of the water. As the acid becomes ſtronger it alſo becomes clearer and leſs coloured in conſequence of a portion of acid re-acting on the impurities with which it is tinged, and thus deſtroying them. When the acid is thus brought to the required denſity and clearneſs, it is poured out of the retorts into large globular glaſs bottles, ſurrounded with wicker work

[a] Fragoſo de Sequeira in Journ. de Phyſ. vol. 51. p. 40.

stuffed with straw (called *carboys*) and is then brought into the market, under the name of *Oil of Vitriol*.

The sulphuric acid obtained from the distillation of green vitriol exists ready formed in the salt, its extrication is a perfectly simple process, and the only impurities that it can possibly contain are sulphurous acid, and a very minute portion of oxyd of iron, and of the earth of the retort. When loaded with sulphurous acid it has a suffocating odour, and when exposed to the air gives out a white vapour like strong muriatic acid; it used formerly to be sold in this state by the name of *fuming oil of vitriol*, and was further distinguished by its property of congealing into a soft ice, at a very moderate degree of cold. By dilution with a little water, and subsequent boiling for a few minutes in a glass vessel, the sulphurous acid is driven off, and the residual fluid is common sulphuric acid in a state of very considerable purity.

It might be imagined *a priori*, that sulphur would be convertible by simple combustion into sulphuric acid, this however is by no means the case. In the first rude attempts to obtain sulphuric acid by this process, the method employed was the following: a large shallow bason was half-filled with hot water, and an earthen crucible, or other convenient vessel filled with melted and ignited sulphur, was fixed by means of a stand in the middle of the bason, and just above the surface of the water; a large bell glass was then whelmed over the pot of sulphur, and brought nearly though not quite in contact with the water; in this situation the vapour arising from the combustion of the sulphur, rose into the bell glass where it mixed with the steam of the hot water, and condensing trickled in drops down the sides of the glass into the bason. But though by this process a certain quantity of sulphuric acid was obtained, yet so large a portion of the sulphur escaped in incondensible suffocating sulphurous acid gas as to render it both a very offensive and uneconomical mode of proceeding. Nor does the want of success in these experiments appear to have arisen from any imperfection of the apparatus or want of care in the manipulation, for they have since been repeated by various manufacturers on a great scale, but with the same result as at first. Chaptal appears to have bestowed particular care on this subject, we shall therefore state the results of his experiments.[b] The apparatus employed by this able chemist was a leaden chamber with a stove constructed on the outside, and communicating by means of a flue with the chamber. In this stove the sulphur was melted, and a blast of air being directed on its surface, combustion took place, and the products of this combination passed into the leaden chamber, and were thus brought in contact with the water which it contained. When the current of air passed very rapidly over the sulphur, only a very small quantity of this latter suffered combustion, the greater part being simply involved in the air in a minutely divided state, and deposited within the chamber in the form of flowers of sulphur. By moderating the rapidity of the current of air, the combination of the sulphur with oxygen is more complete, a large quantity of sulphurous acid is produced, and part of the sulphur is found covering the surface of the water in form of a thin elastic skin. If the current of air is rendered still slower, so as but just to keep up the combustion, the whole of the sulphur is acidified, but so large a portion of it is in the state of incondensible gas, that the product of true sulphuric acid is altogether insignificant. In one of M. Chaptal's experiments he burnt in the course of seven days 1135 lbs. of sulphur, at the end of which time so prodigious a quantity of suffocating gas poured out from the chamber as to render it necessary to stop the process; in three or four days after, the door of the chamber was opened, and after the gas had escaped, it was found that the water on the floor of the chamber was covered with a flexible skin of sulphur, and was scarcely at all acidulous to the taste.

In a second experiment the combustion was much slower, 2900 lbs. being burnt in the space of thirty-three days; during the process much sulphurous acid gas escaped, and on the chamber being opened there was no appearance of sublimed sulphur or of film upon the water, so that the whole of the sulphur had undergone combustion, but the product of condensible acid was so small that the water was only slightly acidulous, and scarcely effervesced with carbonated alkali. Hence it appears, that though atmospheric air will effect the combustion of sulphur, yet the product is little else than incondensible sulphurous acid.

Several other methods have been tried to supercede the necessity of employing nitre, but with little or no success. Water contains a large proportion of oxygen in its composition,

[b] An. de Chim. ii. p. 36.

and is readily decomposeable at a moderate heat by a variety of substances, attempts have been accordingly made to employ it for the oxygenation of sulphur. If to some of this latter when melted and ignited, there be added water drop by drop, at short intervals, the flame of the sulphur will be enlarged, its colour will become of a yellowish tinge, and a dense white vapour will arise from it, but this latter when condensed appears to be only very slightly acidulated water highly charged with minutely divided sulphur.[c] A more likely method of producing sulphuric acid was by mixing with the sulphur a portion of black oxyd of manganese, capable of furnishing a quantity of oxygen equal to that contained in the proportion of nitre usually employed, but though this mixture has been treated in various ways, it does not appear capable of furnishing a greater quantity of sulphuric acid than when sulphur is simply burnt in atmospheric air. Even oxygen gas itself when distributed by means of a pipe over the surface of heated sulphur is by no means comparable in in efficacy to nitre; the rapidity of the combustion is indeed very rapidly increased, but the product is almost entirely sulphurous acid gas.

When the method of producing sulphuric acid by the combustion of sulphur and nitre was first discovered, the apparatus employed was a series of very large glass balloons, at the bottom of each of which was a little water to condense the vapour; only a small quantity of the mixture could be burnt at once, and constant superintendence was necessary to supply the balloons with fresh charges of the materials. In order to save much of this manual labour and the heavy loss arising from the frequent fracture of the vessels, leaden chambers were made use of, which besides requiring less attendance, and being upon the whole cheaper, rendered it easier for the manufacturer to extend his establishment to any required magnitude. These chambers are of various construction; the most simple and in most general use, are furnished only with two apertures, namely, a small door, by which the water and the sulphur and nitre are introduced, and a leaden pipe, with a stop-cock, by which the water when acidulated is drawn off; other chambers have besides a few small apertures for the introduction of atmospheric air during the combustion, and a steam pipe connected with a boiler, it being found that if the water is introduced in the state of steam, a much more rapid condensation of the acid ensues than in the usual way of proceeding. In some of the best contrived chambers the combustion of the nitre and sulphur is effected in a separate stove, and the acid vapour thus produced is poured by means of a pipe into the condensing chamber.

There is a good deal of difference among the manufacturers as to the proportion of nitre employed, by some it is made equal to $\frac{1}{7}$ of the sulphur, while by others it is not allowed to exceed $\frac{1}{16}$. This however appears to be satisfactorily established, that within the above limits the greater the proportion is of nitre, the more easily condensible will the acid vapour be, and the less sulphur will be lost in the form of sulphurous acid gas. If the nitre exceeds $\frac{1}{5}$ of the sulphur, the combustion will be so rapid as to drive into the chamber a considerable proportion of sulphur unaltered. The acid vapour is of a dense opake white colour, and according to Chaptal is considerably luminous: when as much of it is condensed as is capable of being so in the usual process, the residue becomes quite transparent, and is for the most part a mixture of sulphurous acid gas and nitrous gas; it has a peculiar and very pungent suffocating odour, and upon opening the door of the chamber, it presently acquires a faint orange red colour, by combining with the oxygen of the air, and thus forming nitrous acid vapour; this as soon as formed re-acts on the leaden lining of the chamber, corroding it deeply, and is the principal cause of the sulphat of lead, which common sulphuric acid always contains, and often in considerable abundance. It would conduce much to the purity of sulphuric acid, and might probably be found even to be an economical plan, to line the chamber with glass instead of sheet lead; the general appearance of the chamber would then resemble a greenhouse, and all the wood work should be faced internally with glass; a composition of wax, mastich, and fine sand, would form a strong cement for the glass, and little liable to be acted on by acid vapours, more especially if the interstices filled up with it were dusted with powdered glass or very fine sand, while the cement was yet warm and adhesive. Such a chamber would have the additional advantage of allowing the operator to see what was passing within, without the necessity of opening the door.

With regard to the strength of the acid when withdrawn from the condensing chamber, we

[c] Chaptal, Application de Chimie aux Arts, &c. Vol. II.

are informed by Chaptal, that in his manufactory it used to mark between 40° and 50° on Beaumé's areometer; it was then evaporated in leaden boilers, till it arrived at 60° of Beaumé, and was lastly condensed in glass retorts till it was equal to 66°, and was then at the common density of the oil of vitriol of commerce. We are told by the same author, that one part of sulphur affords nearly two parts of sulphuric acid at the above density: this however appears to be a mistake. We should imagine that in the common manufactories the loss by sulphurous acid gas would nearly counterbalance the increase from the addition of oxygen and water; indeed it is expressly stated by some authors that 100lbs. of sulphur produce by combustion an equal weight of sulphuric acid.

It has been already mentioned that the common English sulphur (and probably all that which is obtained during the roasting of copper ore) is unfit for the preparation of sulphuric acid, on account of a yellowish-brown colour that it gives to this fluid, and which it is extremely difficult to get rid of. For this reason the refined Sicilian sulphur is the only kind that is employed in this manufacture, at least in Britain. But though by the due selection of sulphur one source of impurity is avoided, yet there are others which, according to the usual mode of preparing this acid, it is impossible to escape. The watery acid as it runs from the leaden chamber, is necessarily mixed with sulphat of lead, with a small quantity of nitrous acid, and holds suspended in a minutely divided state a portion of sulphur, from which it acquires a yellowish colour: during the evaporation in the leaden boilers, probably a little more sulphat of lead is taken up. The high heat required for the final concentration of the acid in the glass retorts, by causing the nitrous and part of the sulphuric acid to re-act on the diffused sulphur and other inflammable impurities, takes away, for the most part, the colour from the fluid, and drives off the whole of the nitrous gas and sulphurous acid, together with a portion of water: thus the only impurity that finally remains in the sulphuric acid is sulphat of lead. But it not unfrequently happens that the acid during concentration loses its colour very slowly, to expedite which it is usual to add a little nitre, the acid of which being set at liberty acts rapidly on the colouring matter and destroys it, being itself finally driven off in the state of nitrous gas. The alkaline base of the nitre however remains dissolved and combined with the sulphuric acid, so that besides sulphat of lead it is further contaminated by sulphat of potash, and if the nitre is added somewhat in excess, and only a little while before the concentration is finished, it is very probable that a portion of nitrous acid will still remain. Nor is it of trifling moment that the whole of the nitrous acid should be expelled, for if the dyer or callico printer employs an impure acid of this description in making Saxon blue (sulphat of indigo) he will find to his cost that he has got a green instead of a blue pigment. From the occasional occurrence of the above and other similar disappointments it is that the dyers on the continent, when they can procure either the sulphuric or the genuine *vitriolic* acid, always prefer the latter, notwithstanding the great superiority of its price.

Common sulphuric acid may be freed from the sulphats of lead and potash which it generally contains, by distillation; this, however, though apparently a very simple process, is rather a nice matter to manage, according to the usual method. Sulphuric acid is not capable of being distilled at less than a red heat, when therefore the dense hot vapour first comes in contact with the necks of the retort and receiver, it is apt to break them, unless the precaution has been taken of thoroughly heating them by means of a pan of charcoal placed beneath, a minute or two before the distillation commences. All this risk however may be avoided (and in some laboratories it actually is so) by connecting the glass body, in which the acid is boiled, with the receiver, by means of a tube of platina: boiling sulphuric acid has not the least action on this metal, and the vapour in its passage through becomes so far cooled and condensed, that it flows into the receiver in drops.

Sulphuric Acid, when pure, is perfectly transparent and colourless; but the common oil of vitriol of the shops has almost always a very pale hair brown tinge, probably arising from the carbonization of a little of the cement with which the bottles in which it is kept are closed. In its general appearance and consistence when shaken it is not unlike oil, whence it derived its commercial name *oil* of vitriol. It is entirely inodorous: to the touch it is at first smooth and unctuous, but it presently after excites a violently burning sensation, and corrodes the skin with great rapidity; even when largely diluted with water, it is acerb and intensely sour, and sets the teeth on edge. It changes most vegetable blues to red, and exhibits the other generic characters of acids in an eminent degree. Concerning the utmost possible density of this acid in an uncombined state, there is a

remarkable difference among chemical writers, according to Beaumé and Bergman it sometimes amounts to 2.125. According to Wiegel, the specific gravity of the fuming glacial sulphuric acid is = 1.898, while that of the English sulphuric acid cannot be brought higher than 1.851. Mr. Perceval[b] found that common sulphuric acid of the specific gravity of 1.842, after being heated to redness for half an hour in a retort, during which time it emitted copious white fumes of sulphuric acid and sulphurous acid gas, was increased to 1.852: but this concentrated acid was impure, since by dilution with water it deposited a white powder, probably sulphat of lead; being then distilled, the acid that came over appeared to be perfectly pure, and when concentrated by being heated for some time in a retort, its sp. gr. was found to amount to 1.846. Hence it appears that there is a real difference in the extreme densities of sulphuric acid made from sulphur and that procured from the distillation of martial vitriol. Nor is this at all surprising if we attend to the circumstances of their production. The sulphuric acid when combined with oxyd of iron, with which it has a strong affinity, and which is itself fixed in the fire, will necessarily be capable of being dephlegmated to a much higher degree than when the acid is exposed to the action of heat in an uncombined state as is the case in the concentration of the English sulphuric acid.

The fixity of sulphuric acid is very considerable: when in the state of common oil of vitriol it requires nearly a red heat for its vaporization, and though when diluted with water it will boil at a considerable lower temperature, yet little else than water is driven off, and the acid becoming more and more concentrated, requires a continually increasing heat to keep up its ebullition till it arrives at the degree necessary for the volatilization of the acid itself.

Sulphuric acid freezes, or crystallizes, by exposure to cold, and it appears to congeal with more ease when moderately concentrated than when it is dilated: this remarkable circumstance was first pointed out by the Duc d'Ayen, was then confirmed by Morveau, and has since been treated at large and in a very satisfactory manner by Mr. Keir.[d] This accurate observer found that sulphuric acid of the sp. gr. of 1 78, congeals at about 40° Fahr. but that if the density is either increased or diminished, a greater cold is required for its congelation. Proceeding from the above density in each direction, he found that sulphuric acid at the sp. grs. of 1.786 and 1.775, or at any intermediate density, freezes when exposed to the cold of melting snow; that if the energy of the freezing mixture be increased by the addition of common salt, it will congeal sulphuric acid at the sp. grs. of 1.841 and 1.75, or at any intermediate density; but that acid at the sp. grs. of 1.815 on the one hand, and 1.745 on the other, continue fluid. Sulphuric acid while freezing contracts considerably in its dimensions; sometimes it forms a confused mass, but often shoots into large regular crystals in the form of oblique truncated octohedrons, or compressed hexahedral prisms, terminated by hexahedral pyramids.

Sulphuric acid unites very eagerly with water. If some of the former at the usual density of 1.845 be mixed with ¼ of its weight of water, the temperature of the mass instantly rises to near 300° Fahr. and a mutual penetration takes place, the density of the compound being greater than the mean density of its ingredients. If even four parts of sulphuric acid and one of ice, both at the temperature of 32°, be mixed together, the heat of the mass will rise to 212°, but if the proportion of ice be increased considerably, the caloric necessary to the liquid state of the mixture will exceed that which is extricated during the combination of the ingredients, and cold will be produced; thus if four parts of ice and one of acid at 32° be mixed together, the temperature of the mass will be cooled down to —4°. But in all cases where concentrated sulphuric acid is employed in the composition of freezing mixtures, there is at the moment of their combination, as Beaumé has well observed, a very sensible production of heat, which must materially diminish the frigorific effect; thus according to the able chemist last mentioned,[f] if one part of sulphuric acid at the common temperature, and four parts of ice, be mixed together, the first effect is to raise the thermometer in an instant to 94° F. from which it sinks as speedily to 32°. But if the acid has been previously diluted with water, the temperature sinks on the addition of ice to 5° F. without any previous heat having been excited. So powerful is the affinity of sulphuric acid for water that it will absorb moisture with great rapidity from the air, so as in a very few days to double or treble its weight. Even a boiling temperature, when the acid is moderately concentrated, will not counter-balance this strong tendency; hence it is that sulphuric acid cannot by boiling in an

[d] Irish Phil. Transf. vol. iv. p. 88. [e] Phil. Transf. for 1787, p. 267. [f] Chem. Exper. I. p. 419.

open veſſel, be concentrated nearly ſo much as by diſtillation in a cloſe apparatus.

It does not appear poſſible to obtain the ſulphuric acid free from water, except it is combined with ſome alkaline or earthy baſe; but as it is a matter of ſome importance, both in chemical experiments, and in ſeveral manufacturing proceſſes where this acid is employed, to aſcertain the real ſtrength of mixtures, containing different proportions of acid and water, ſeveral chemiſts have engaged with various ſucceſs in this intereſting enquiry. Upon the whole the experiments of Mr. Kirwan, corrected as they have been by the obſervations of Morveau and Berthollet, ſeem entitled to moſt confidence, and are ſufficiently exact to anſwer every practical purpoſe. The method by which Mr. Kirwan has reſolved this important problem is the following.[a] He took ſome purified cream of tartar, and calcined it in a ſilver crucible till the tartaric acid was entirely deſtroyed; from the reſidue by lixiviation with diſtilled water, he obtained a ſolution of pure ſubcarbonat of pot-aſh, which, after evaporation to dryneſs and ſubſequent ignition, weighed 1523. 5 grs. This ſalt was then diſſolved in water, and the whole weight of the ſolution amounted to 4570 grs. Of this latter ſolution 360 grs., containing 120 grs. of ſubcarbonat of potaſh, were ſaturated with 130 grs. of a ſulphuric acid, the ſpecific gravity of which at 60° F. was $=$ 1.565. During the combination of the ſulphuric acid and the alkali, 34 grains of carbonic acid which had previouſly been combined with the alkali were expelled, therefore the amount of pure potaſh in the ſolution was $= 120 - 34 = 86$ grs. Water was now added to the ſolution till it amounted to 3694 grs. of which the ſp. gr. at 60° F. was $=$ 1.013. Next, 45 grs. of ſulphat of potaſh were diſſolved in 1017 grs. of water, and the ſp. gr. of this ſolution was exactly equal to that of the one juſt mentioned; but in this latter ſolution the proportion of ſalt to water was :1:23.6, and the ſpecific gravities of both ſolutions being the ſame, the ſalt in each muſt alſo bear the ſame ratio to the water. Therefore in the former ſolution the amount of ſalt was $= \frac{3694}{23.6} =$ 156.52 grs. now of this, 86 grs. were potaſh, hence the remainder, namely 70.5 grs., were acid in the ſtate of concentration in which it exiſts in ſulphat of potaſh; but ſulphat of potaſh loſes ſcarcely any perceptible weight by ignition, from which it may be inferred that it contains little or no water of cryſtallization, and that it is compoſed of mere or *real* acid and potaſh. Therefore 130 grs. of ſulphuric acid at 1.565 contain 70.5 of real acid, and 100 parts of the ſame diluted acid contain 54.2 of real acid.

By a ſimilar method the proportion of real acid in ſulphuric acid of the ſpecific gravity of 2.0 or *ſtandard* acid was aſcertained, and by diluting this acid with various proportions of water, the quantity of ſtandard or real acid in acid of any ſpecific gravity between 2.0 and 1.0955 was found. But when ſulphuric acid and water are mixed together, a mutual penetration takes place, in conſequence of which there is an increaſe of ſpecific gravity. This augmentation was found to amount to about $\frac{1}{75}$ of the whole denſity. The gravities as found by experiment being corrected accordingly, a table was conſtructed ſhewing the ſpecific gravity of any mixture of ſulphuric acid and water, from the moſt concentrated oil of vitriol, down to one ſo dilute as to contain only 1.78 per cent. of real acid. This table will be given in the Appendix.

The component parts of ſulphuric acid are well known to be ſulphur and oxygen, as may be demonſtrated either by analyſis or ſyntheſis; thus if ſulphur be digeſted with nitric acid, nitrous gas will be given out from the decompoſition of the acid, while the oxygen, the other element, will combine with the ſulphur, and form with it ſulphuric acid; on the other hand, if ſulphat of ſoda be mixed with charcoal, and expoſed to a red heat, the ſulphuric acid is deoxygenated by the ſuperior affinity of the charcoal; carbonic acid and carbonous oxyd are produced, and the ſulphat of ſoda is found to be converted into ſulphuret of ſoda, from which the ſulphur may readily be procured by ſolution in water, and the addition of an acid.

But though the elements of ſulphuric acid are aſcertained, much doubt ſtill exiſts with regard to their relative proportions, we ſhall therefore enter with ſome minuteneſs on this part of the ſubject. Three methods have been followed in attempting to reſolve this important queſtion. The firſt that we ſhall mention, and apparently the moſt direct, was employed by Lavoiſier. He placed a given weight of purified ſulphur in a receiver, with a little water to abſorb the acid produced, then ſetting fire to the ſulphur, he ſupplied it with oxygen gas of known purity, till the combuſtion ceaſed, then by aſcertaining the weight of ſulphur burnt, and of oxygen gas conſumed, he infer-

[a] Iriſh Phil. Tranſ. vol. iv.

red that sulphuric acid was composed of 71 parts sulphur to 29 parts oxygen. In this estimate however the proportion of sulphur is manifestly exaggerated, for by the combustion of sulphur in oxygen gas, a quantity of sulphurous acid will be produced as well as of sulphuric, the former of which contains a much greater proportion of sulphur than the latter.

The second method is that by Berthollet, as follows. Having ascertained that nitre and sulphur in the proportion of four parts of the former to one of the latter when heated in a retort, re-acted on each other quietly and without explosion, he mixed together 288 grs. of nitre, and 72 grs. of sulphur, and heated the mixture in a glass retort till the emission of nitrous gas entirely ceased: during the process, 12 grs. of sulphur had sublimed unaltered, and 228 grs. of sulphat of potash were produced by the combination of the alkaline base of the decomposed nitre with the newly produced sulphuric acid. Now according to Kirwan, sulphat of potash is composed of 45.2 sulphuric acid, and 54.8 potash, therefore out of the 228 grs. of sulphat of potash, 103 grs. were sulphuric acid, composed of 72—12 = 60 grs. sulphur, and 43 grs. oxygen; hence 100 parts of sulphuric acid consist of

58.2	Sulphur
41.8	Oxygen
100.0	

The third method, which has been followed by Berthollet, Thenard, and Chenevix, and which appears upon the whole the best, is to digest a given weight of sulphur in nitric acid, till it is completely dissolved and acidified (which if performed with care may be effected without the production of any sulphurous acid) then to add a solution of nitrat or muriat of barytes as long as any precipitate takes place, by which the whole of the newly-formed sulphuric acid will combine with barytes into an insoluble salt; then to edulcorate and ignite the sulphated barytes, and from its weight to deduct that of the barytic base; the remainder consequently will indicate the amount of sulphuric acid produced, from which by subtracting the known weight of sulphur, we get by inference that of the oxygen. But though this mode of proceeding is apparently unexceptionable, yet unfortunately the differences in the quantity of sulphat of barytes produced, and in the estimates of the component parts of this earthy salt are so prodigious as to throw great uncertainty upon the subject. In the experiments of Berthollet,[g] 288 grains of sulphur being digested with nitric acid, 199 grs. remained undissolved, therefore 89 grs. were acidified; muriat of barytes being added there was produced 948 grs. of sulphated barytes, which by ignition was reduced to 920 grains, therefore 100 grs. of sulphur would have afforded 1033 grs. of sulphated barytes.

On the other hand, Mr. Chenevix[h] acidified 100 grs. of sulphur by digestion in nitric acid, and by the subsequent addition of nitrated barytes obtained 694 grs. of sulphated barytes.

Lastly, M. Thenard,[i] by operating in a similar manner, obtained from 100 grs. of sulphur 720 grs. of sulphated barytes.

The above differences in the results of experiments made by men of acknowledged skill in chemical analysis, are of themselves sufficient causes of uncertainty, but the difficulty of deciding will be much increased when these variations are further modified by the different estimates of the component parts of sulphated barytes. According to Klaproth, Withering, and Black, this salt contains about 33.33 per cent. of acid. According to Chenevix, it contains 23.5 of acid; and according to Thenard, 25.18 of acid. (See SULPHAT OF BARYTES.

Hence by compounding the above results, the 1033 grs. of sulphated barytes, obtained by Berthollet, indicate the composition of sulphuric acid to be according to

Klapr.		Thenard.		Chenev.
24.3	—	37.4	—	41.2 Sulphur
75.7	—	62.6	—	58.8 Oxygen
100.		100.		100.

The 694 grs. of sulphated barytes obtained by Chenevix, from the acidification of 100 grs. of sulphur, indicate the composition of sulphuric acid to be according to

Klapr.		Thenard.		Chenev.
43.2	—	57.4	—	61.5 Sulphur
56.8	—	42.6	—	38.5 Oxygen
100.		100.		100.

And the 720 grs. of sulphated barytes, obtained by Thenard, indicate the composition of sulphuric acid to be according to

g Encyclop. Method. Art. Acide Vitriolique. h Phil. Trans. i An. de Chim. xxxii. p. 266.

Klapr.	Thenard.	Chenev.	
41.8 —	55.56 —	59.1	Sulphur
58.2 —	44.44 —	40.9	Oxygen
100.	100.	100.	

It has been stated by some chemists that sulphuric acid is capable of combining with an additional quantity of oxygen, if distilled slowly with oxyd of manganese. This experiment was however repeated without success by Vauquelin and Bouvier;[k] sulphuric acid and oxygen gas came over, acidulous sulphat of manganese remained in the retort, and the sulphuric acid on examination did not appear to differ in the smallest circumstance from common rectified acid.

Muriatic acid gas combines readily, and in considerable abundance with sulphuric acid; the compound acquires a brownish tinge, and when exposed to the air emits dense white fumes of muriatic acid gas, probably mixed with a little sulphuric acid, as their odour is more pungent and suffocating than that of simple muriatic acid.

The nitric and sulphuric acids unite together readily, either by direct mixture or by adding a little nitre to sulphuric acid. This compound when moderately concentrated has the property of dissolving silver without materially acting on copper; hence it is in considerable use for recovering the silver from clippings and other refuse of the manufactories of silver plate.

Sulphuric acid absorbs by agitation a considerable quantity of red nitrous vapour,[l] and in consequence acquires a light blue colour. The mixture when exposed to the air gives out a white vapour. If water is added the great heat that is thereby generated causes a very rapid and copious emission of the nitrous vapour, and sulphuric acid and water alone remain behind. Sulphuric acid thus impregnated with nitrous vapour after a time becomes nearly colourless, and then concretes into solid crystals; in this state when dropped into water it acquires a green colour, and both the crystals and water sparkle with the spontaneous and copious production of nitrous gas. When the crystals are simply exposed to heat they melt, emit a dense red fume, and after the nitrous vapour is thus driven off, the residue is common sulphuric acid.

None of the simple combustibles appear to have any action on sulphuric acid at the common temperature, but at a high heat they are all capable of deoxygenating this acid, and reducing it to the state partly of sulphur, and partly of sulphurous acid. Thus if sulphur and sulphuric acid are boiled together, the acid takes up a small portion of sulphur, acquires thereby a yellowish colour, and the peculiar suffocating odour of sulphurous acid. In like manner if sulphuric acid is distilled off phosphorus, a large production of sulphurous acid takes place, and phosphoric acid remains behind in the retort. Charcoal in the same manner deoxygenates this acid. The action of hydrogen upon it is remarkably energetic; if some pure sand moistened with sulphuric acid, be strongly heated in an earthen-ware tube, and at the same time exposed to a stream of hydrogen gas, a copious production of sulphur and water will ensue from a total decomposition of one part of the acid, and the combination of its oxygen with the hydrogen; accompanied also by sulphurous acid arising from an imperfect decomposition of the other portion of acid. All the common metals except gold and platina also decompose sulphuric acid at a boiling heat; the metal is oxydated and the acid is converted into the sulphurous. But when an acid sufficiently diluted is made use of, those metals that have a powerful affinity for oxygen decompose the water in preference to the acid, whence hydrogen gas is given out, while those whose affinity for oxygen is weaker, as silver and mercury, exert no action either on the acid or water.

Concentrated sulphuric acid, even when cold, acts in a very striking manner on most kinds of vegetable and animal matter; if a piece of paper or straw, for example, be immersed in sulphuric acid, the texture of the straw is speedily broken down, it acquires a deep black colour, and is diffused through the acid in a state of half solution. This phenomenon however does not take place, as is generally supposed, on account of the reaction of the sulphuric acid on the carbon and hydrogen, producing sulphurous acid, but from the strong affinity of the acid for water, in consequence of which, the oxygen and hydrogen of the vegetable matter, combine together into water, while the carbon is precipitated. But of this we shall treat more fully in the article Vegetable Matter.

Sulphuric acid combines with all the metallic oxyds, with the alkalies, and all the earths except silex, forming an important genus of salts, called in the reformed nomenclature, *Sulphats*, which see.

[k] Ann. Chem. vii. p. 287.
[l] Priestley's Exper. Method. iii. p. 144, 156.

The following is the order of the affinities of sulphuric acid. Barytes, strontian, potash, soda, lime, magnesia, ammonia, glycine, yttria, alumine, zircon, metallic oxyds.

The uses of sulphuric acid are numerous and very important. It is employed in the laboratory in the preparation of the nitric, muriatic, fluoric, phosphoric, and many other acids; it is a useful agent in various processes of chemical analysis. It is largely used in the arts, particularly by the dyer and callico-printer, and is of no small importance as an article of the materia medica.

SULPHURIC ACID, *fuming*, or *Glacial*.

In the preceding article we have briefly noticed some of the characteristic properties of the glacial sulphuric acid, or that obtained from the distillation of calcined sulphat of iron: we now proceed to relate them more at large, as having been the occasion of much controversy among the continental chemists, particularly those of Germany. This acid used to be, and perhaps is still, prepared at Nordhausen in Saxony; it is of a dark brown colour, and exhales, when exposed to the air, abundance of dense white suffocating vapours; its usual specific gravity is = 1.95. When distilled in a glass retort, by the time that a small portion has come over, the remaining acid is nearly colourless, and of a somewhat less specific gravity than the entire acid; it no longer exhales any vapours, and except in superior density, it does not appear to differ from the common sulphuric acid. The fluid and vapour contained in the receiver as they cool down gradually to the temperature of the atmosphere, begin to congeal; the vapour forms radiated crystals on the top and sides of the receiver, while the bottom is occupied with a confusedly crystalline mass, differing in density according to the specific gravity of the acid before distillation. Hence it is obvious, that the fuming acid of Nordhausen, differs from common acid in being mixed or combined with a crystallizable substance more volatile than sulphuric acid. This substance was supposed from its suffocating odour to be sulphureous acid, accordingly, experiments were made by M. Dollfuss and others, to restore the clear rectified acid to its former state, by digesting it with charcoal, sawdust, oil, alcohol, and other deoxydating substances; but though the acid by this means acquired a brownish black colour and a sulphurous odour, it was hardly at all fuming when exposed to the air; and on distillation it afforded a weakly acid sulphurous liquor, which neither congealed nor emitted white vapours. From the results of these experiments M. Dollfuss concluded that the fuming and glacial quality of the Saxon sulphuric acid was owing to the presence of a peculiar volatile salt.

In order more compleatly to elucidate the matter, a series of experiments was undertaken by M. Morveau. He took 4 lbs. of green vitriol, and by careful calcination reduced its weight to 28 ounces; these were put into an earthen-ware retort and distilled at the full heat of a reverberatory furnace. When the retort began to grow red, a weak acid came over in drops during about half an hour; the receiver was then changed, and as the heat increased, white vapours began to make their appearance. To the receiver was attached a pneumatic apparatus, in order to collect the gas produced, which being examined from time to time it appeared, that during the first three hours, little else came over than atmospheric air, which was then succeeded for the next hour and a half by sulphurous acid gas either pure or at least mixed with no oxygen; by degrees however it became diluted with oxygen gas, and during the next four hours and a half (after which the process was put an end to) a large quantity of oxygen gas was produced, mixed however during the whole time with sulphurous acid. The fluid in the receiver was of a brown colour, and being exposed during the night to a temperature of 47° Fah. was found in the morning to be congealed into a solid mass of crystals, with the exception of a few drops of a brown liquid.

As soon as the receiver was separated from the retort, it was instantly filled with white vapours which poured out so rapidly as in a short time to fill the whole laboratory; these fumes, though somewhat sulphurous, were by no means suffocating. A few drops of water being sprinkled on some of the concrete acid, caused a hissing noise like that of a bar of iron plunged in cold water, and the acid immediately melted and entirely lost its fuming property. If the stopper of the vessel in which the glacial acid is kept be often taken out, the crystals at length resolve themselves into a brown liquor, and if this is again subjected to distillation there comes over an acid, at first highly sulphurous, but becoming less so as the process goes on; no portion however of the distilled product is in the least degree fuming or congealable at the common atmospheric temperature.

From these facts it appears probable that the

essential difference between the common and glacial acid, is that the latter from the mode in which it is prepared contains a smaller portion of water than the former, and that to this is owing both its volatility and property of congelation; it is incidentally mixed with sulphureous acid, but the presence or absence of this, does not appear to be of any material importance.

SULPHATS.

Under this article we shall describe the salts produced by the union of sulphuric acid with the alkalies and earths. The metallic sulphats are described under the several metals.

All the sulphats form crystallizable salts with these bases, except with alumine, which requires the presence of potash or ammonia to be able to crystallize. The sulphats are scarcely decomposable by heat alone, but when fused in contact with charcoal or any carbonaceous matter, they are converted more or less compleatly into *sulphurets*, as has been described under that article. They are all insoluble in pure alcohol. The solutions of these salts are decomposed by the other salts of barytes entirely, and by the salts of lime nearly so, the acid forming a precipitate with these earths. A similar decomposition takes place when any sulphat is added to the soluble salts of lead, silver, and other metals whose sulphats are little soluble. None of the sulphats are entirely decomposed at a moderate temperature by any other acid, the sulphuric standing the highest in the order of affinity, with a very few exceptions. But some of the acids partially decompose the sulphats, and by taking part of their base they reduce the remainder to the state of acid sulphats. The nitric and muriatic acids are of this kind, and the tartareous, with regard to the sulphat of potash. But the acids that are fixed in the fire, such as the boracic, phosphoric, and arsenic, decompose the sulphats totally in a red heat long continued.

SULPHAT OF POTASH, or *Vitriolated Tartar*.

This salt may be formed by the direct combination of sulphuric acid and potash, or carbonat of potash, but being of little value it is never prepared in this way, as it is produced in the distillation of nitric acid, being the residue of the decomposition of nitre by sulphuric acid. This residue, which is a hard, white, acid, saline mass, contains sulphat of potash, generally with a little nitrous acid or with an excess of sulphuric acid. It should be dissolved to saturation in boiling water, nearly saturated with carbonat of potash, in case the acid is in considerable excess, and on cooling gradually the sulphat of potash separates in small crystals. The whole crystalline mass taken out after the liquor is perfectly cold, and has stood at rest for a day, is nothing but sulphat of potash, which by re-solution in warm water, and cooling more gradually, may be obtained in larger crystals. The form of this salt is generally that of a six-sided prism terminated by as many pyramids, like that of a quartz crystal.

Sulphat of potash is the least soluble of all the sulphats, requiring about fifteen times its weight of cold water, but only five parts of boiling water, so that much of it readily separates from the hot solution when saturated. The salt is very hard and readily reducible to powder, and its taste is saline and bitter. It is perfectly permanent in the air, neither deliquescing nor effervescing.

On account of the sparing solubility of this salt it is often separated in the form of a precipitate from watery solutions as soon as it is formed. Thus if moderately concentrated sulphuric acid be added to a strong solution of potash or carbonat of potash, the mixture becomes almost immediately thickened with a large quantity of hard white powder which is the sulphat of potash formed and precipitated at the moment of mixture.

This salt is one of the most easily distinguishable of the saline substances, by its hardness, little solubility, and bitter taste, and general pyramidal form of its crystals.

When a crystal of sulphat of potash is suddenly heated it decrepitates, and splits asunder with some violence. It then parts with its water of crystallization which is not more than 1.4 in 100, according to Dr. Thomson. At a red heat it melts, but does not undergo further alteration.

According to Mr. Kirwan, 100 parts of the dry decrepitated salt, consist of 54.8 of potash, and 45.2 of acid, which agrees very nearly with the experiments of Dr. Black; and 100 grs. of the salt dissolved in water, and precipitated by muriated barytes give 135.25 grs. of ignited sulphat of barytes. But on the other hand, Dr. Thomson,[a] found that 100 parts of the crystallized salt lost 1.4 by fusion, which is therefore the water of crystallization, and that the residue dissolved in water and precipitated by muriated barytes gave only 128 parts of

[a] System of Chemistry.

ſulphat of barytes, inſtead of 135.25. The quantity of ſulphuric acid indicated by a given quantity of *ſulphat of barytes* is differently eſtimated as will be mentioned under that head, but the difference between 128 and 135.25 grs. in an experiment performed by two able chemiſts, as appears, preciſely in the ſame way, is not very accountable, particularly with ſo fixed a ſubſtance as ſulphat of barytes, which may be deſiccated thoroughly with ſo little riſk of loſs.

Acid Sulphat of Potaſh.

If common ſulphat of potaſh is put into a glaſs, or better, a platina veſſel, and ſulphuric acid poured upon it, and heat applied, the maſs firſt melts into an uniform denſe limpid fluid, which when it has arrived at the heat at which ſulphuric acid boils, ſends forth an abundance of white vapour, which is the exceſs of acid that evaporates. This continues till the quantity of acid left in the veſſel is ſomewhat more than a third of the weight of the ſulphat; but when it approaches this point, the vapour gradually diminiſhes and nearly ceaſes, provided the heat does not exceed that of low redneſs, the ſaline maſs in the veſſel remaining all the time perfectly fluid and limpid. It then has the appearance of a very denſe tranſparent oil, and if removed from the fire, it ſpeedily ſolidifies uniformly and compleatly, and becomes a hard, tough opake-white or greeniſh-white maſs of a ſtriated texture, which is the *ſuper-ſulphat of potaſh*. If the veſſel is returned to the fire, the ſalt again melts quietly, and becomes tranſparent. If the heat is raiſed to full redneſs, the evaporation of the acid again begins, and by continuing the heat long enough, and with ſufficient intenſity, all the exceſs of acid may be driven off, and the neutral ſulphat alone will remain; but the difficulty of evaporation increaſes as the exceſs of acid leſſens, ſo that it would require many hours of pretty ſtrong heat to drive off all the exceſs. The fuſibility of the maſs alſo decreaſes as the acid evaporates.

The ſuper-ſulphat thus obtained (the heat not having exceeded a low redneſs) has a ſtrongly acid taſte mixed with ſomewhat of bitterneſs. It is much more ſoluble in water than the ſulphat, requiring for ſolution no more than twice its weight of water when cold, and leſs than its own weight when boiling. It is very ſlightly deliqueſcent. If moiſtened with a very little water and melted, on cooling it forms a ſofter maſs than before, compoſed of long ſtriæ, ſomewhat flexible, and often of a ſilky luſtre. The ſaturated ſolution of this ſalt in boiling water cryſtallizes on cooling.

Super-ſulphat of potaſh is decompoſed by thoſe ſubſtances that decompoſe the ſulphat, and it is alſo reduced to the ſtate of common ſulphat by any alkali or earth, which unites with the exceſs of acid. The proportions of its conſtituent parts are only uniform when it is cryſtallized, and it is then compoſed of about two parts of ſulphat of potaſh, and one of ſulphuric acid.

The neutral ſulphat is highly uſeful in the manufacture of *Alum*, and a little in medicine. The ſuper-ſulphat is not employed, as it is not produced in any manufacture, and neither of theſe ſalts are of ſufficient value to be worth preparing by the direct combination of their ingredients.

Sulphat of Soda, or *Glauber's Salt*.

This ſalt was firſt diſcovered by Glauber, in 1658, in the reſidue of the diſtillation of common ſalt and ſulphuric acid for procuring muriatic acid. This ſalt and Epſom ſalt, or ſulphat of magneſia, were often confounded together for ſome time after the firſt diſcovery of each, till the real nature of the latter was aſcertained by Dr. Black.

Sulphat of ſoda is found native in a variety of places and both ſolid and diſſolved in natural waters, but on the whole the quantity is but ſmall. The native *Glauber's ſalt* is found in Hungary, in the neighbourhood of ſalt lakes, and is deſcribed under this article. This ſalt is alſo contained in greater or leſs quantity in almoſt every natural water that has any ſaline taſte or quality, ſuch as the Seltzer, Cheltenham, &c. and particularly in many of the hot ſaline ſprings, combined with carbonat of ſoda, of which the celebrated thermal waters of Carlſbad are ſtriking inſtances, and are eſtimated by fair calculation to pour out annually upwards of a million of pounds of this ſalt along with other ingredients. Many brine ſprings alſo contain this ſalt, which remains in the mother water after the extraction of the common ſalt, and may then be obtained by evaporation and cryſtallization on cooling.

Glauber's ſalt is alſo procured in many proceſſes of chemical manufacture, either as a reſidue, or an intermediate product in the preparation of ſoda. A good deal of it is obtained in manufacture as a reſidue in the diſtillation of muriatic acid from ſulphuric acid and common ſalt, or of oxymuriatic acid from ſulphuric acid, common ſalt, and mangane*ſ*e; or in the

manufacture of *sal ammoniac* from sulphat of ammonia and common salt, which last in this country furnishes the greater part of the Glauber's salt in use.

This salt is also obtained by the decomposition of *muriat of soda* by pyrites, and by gypsum, (as described under that article) and is the intermediate step in the manufacture of soda from common salt.

Sulphat of soda in its common state forms long transparent crystals, which are usually six-sided prisms with dihedral summits. Sometimes they are obtained of an enormous size, nearly a foot in length, and an inch in breadth, but commonly their length is from one to about three inches. The taste of sulphat of soda is salt, bitter, and unpleasant. The crystals are soluble in less than three times their weight of cold water, but at a boiling heat no water is required, as they readily liquefy in their water of crystallization. Hence this salt is one of those that crystallizes with the greatest ease from a hot concentrated solution. Considerable cold is produced during the solution of the crystals in water. When the crystals are heated they liquefy in their water of crystallization, and if the heat is continued till the water is entirely evaporated, a hard white saline mass remains, which is the salt unaltered except by the loss of water, so that on re-solution it is obtained in crystals as before. If the dry saline mass be boiled with water till the latter is fully saturated, and the solution poured into a thin phial whilst yet scalding hot, and immediately corked perfectly tight, the liquor does not solidify on cooling if kept quite at rest, but remains fluid and transparent. But on opening the cork, and, if necessary, giving the bottle a gentle shake, an instant solidification begins at the surface, rendering it opake, and proceeds rapidly downwards to the bottom till the whole is compleatly congealed, and may be inverted without spilling a particle. A sensible warmth is felt on the outside of the bottle at the time of congelation. The cause of this is the extrication of the caloric of liquefaction, as explained under the article *Caloric*, p. 207.

When this salt in its crystallized state is exposed to a dry air it soon becomes covered with a mealy-looking powder, and after a time the whole falls into the same white powder, which consists of the salt merely deprived of most of its water of crystallization by the action of the air, and reduced to about half its former weight. Hence the salt should be kept in well-closed bottles to preserve its crystalline form.

The composition of this salt may be inferred from the following facts. According to Klaproth,[b] 1000 grs. of the salt recently crystallized and dried on blotting paper were reduced by thorough drying on a sand-bath to 420 grains, whence the quantity of water of crystallization is 58 per cent. Also 100 grs. of the dried salt dissolved in water, and decomposed by acetited barytes gave 168 grs. of dry sulphat of barytes, whence 42 grains of dry Glauber's salt (the quantity contained in 100 of the crystallized salt) would give 70.56 grains of sulphat of barytes.

Lastly, from the respective quantities of sulphuric acid and soda required for mutual saturation, and from the quantity of dry sulphat of soda thereby produced, Mr. Kirwan estimates the proportions of ingredients in 100 parts of the crystallized salt to be 58 of water, 23.52 sulphuric acid, and 18.48 soda.

Some of the decompositions of sulphat of soda by other salts are interesting. Of these the most curious is that of the formation of this salt in a mixture of sulphat of magnesia and muriat of soda, when exposed to a freezing temperature, which was first remarked by Gren.[c] These salts do not decompose each other in a temperature above freezing, but do it readily and almost compleatly below this point. What is remarkable, this decomposition when once effected is permanent at any temperature, for on raising the heat, Epsom salt and common salt are not regenerated as might have been expected.

Sulphat of soda is decomposed by muriat of lime, and as the sulphat of lime thence resulting is nearly insoluble, most of it precipitates, and the solution contains little else than the regenerated muriat of soda, provided the quantities of each salt have been duly proportioned to each other. When muriated magnesia and sulphat of soda are in solution together, the addition of lime causes the following successive decompositions, viz. the lime first decomposes the muriated magnesia, muriat of lime is formed and pure magnesia is precipitated; and the muriat of lime thus formed then decomposes the sulphat of soda, and muriat of soda remains in solution, whilst sulphat of lime precipitates and mixes with the magnesia, which has before subsided. It is upon these two circumstances, namely, the decomposition of mu-

[b] Essays, vol. i. p. 282.

[c] An. Chim. tom. 24.

riated magnesia by lime, and of Glauber's salt by muriated lime, that Gren has proposed an ingenious method of separating the deliquescent earthy muriats from brine, and increasing the proportion of common salt, by the addition of lime, or Glauber's salt, or both, according to the following cases:

1. If the brine contains, besides common salt, only muriated lime, the addition of Glauber's salt is sufficient, which by decomposing the calcareous muriat produces selenite and common salt, as already mentioned.

2. If the lime contains, besides common salt, Glauber's salt and muriated magnesia, the addition of lime alone will suffice, which, as we have before described, first decomposes the muriated magnesia, and the resulting muriat of lime then decomposes the Glauber's salt.

3. If the brine contains, besides common salt, only muriated magnesia, both lime and Glauber's salt must be added, for obvious reasons.

4. If the brine contains, besides common salt, sulphat and muriat of magnesia, lime and Glauber's salt must also be added.

5. If the brine contains, besides common salt, sulphat and muriat of magnesia, and sulphat of soda, lime alone will be sufficient if the Glauber's salt be in sufficient quantity, if not, an additional quantity of the latter salt must also be added.

We know not whether any of these methods have been adopted in the manufacture of salt in the large way, neither would they be required in the English rock salt and brine works on account of the very small proportion of impurities, and which do not appear to throw much obstacle to the goodness of the salt, but in the salterns from sea-water, where the salts of lime and magnesia are abundant, the ingenious ideas of Gren might be adopted to advantage. The greatest objection would be in the cost of Glauber's salt, but it might be probably collected in winter, from sulphat of magnesia and common salt, at a moderate expense, and from the remaining muriat of magnesia, the earth might then be precipitated by a carbonated alkali.

Sulphat of soda is largely used in medicine, being a very useful, powerful, and cheap purgative. It is no otherwise used in manufacture than as a material from which the soda may be extracted by any of the methods already described under the article muriat of soda.

When sulphat of soda is dissolved in dilute sulphuric acid and set aside to crystallize, it deposits large rhomboidal crystals,[a] which contain an excess of acid, and are therefore a *super sulphat of soda*.

If dry sulphat of soda is heated in a glass or platina vessel with concentrated sulphuric acid, they melt together as the mixture of sulphat of potash and sulphuric acid do, but the acid in this case is readily driven off by a moderate continuance of heat, and the remaining salt redissolved in water, yields crystals of common Glauber's salt.

But a mixture of equal parts of sulphat of potash and soda retain an excess of sulphuric acid almost as obstinately as sulphat of potash alone does. In all these cases the excess of acid may be got rid of most accurately, without affecting the neutral salt, by dissolving the whole in water, supersaturating it with carbonat of ammonia, evaporating the mixture carefully to dryness, and then applying a moderate red heat. A dense white smoke arises before the mixture is red-hot, which is sulphat of ammonia, and by continuing the heat as long as a particle of visible smoke rises, all the excess of acid is volatilized along with the ammonia, and the neutral sulphat of potash or soda, remains perfectly pure, white and dry. It is probable however that a small portion of the neutral salt would be found to have been volatilized along with the sulphat of ammonia, but this loss can only be very small, and the actual quantity might be easily ascertained by a few comparative experiments.

SULPHAT OF AMMONIA. *Glauber's Secret Sal-Ammoniac.*

This salt has not been found native. It may be prepared by saturating moderately dilute sulphuric acid with ammonia, and evaporating considerably. It then crystallizes on cooling, in hexahedral prisms terminated by hexahedral pyramids, or often in silky needled crystals. This salt is produced in the manufacture of sal-ammoniac, but only as an intermediate product, and is immediately decomposed by common salt, producing Glauber's salt and muriated ammonia.

Sulphat of ammonia is very soluble in water, requiring only twice its weight of cold, and much less of boiling water. This salt is very slightly deliquescent in the air. It generates much cold during solution.

When a quantity of this salt is heated *per se* in a retort, and all the products received in

[a] Thomson.

succession,[e] it first liquefies and mere water comes over, after which a considerable quantity of ammoniacal gas is given out, and if the salt in the retort be then examined, it is found to be sulphat of ammonia with excess of acid, and may be dissolved in water and crystallized with this excess, forming a *super-sulphat*. But if the heat is continued, after the ammonia has passed over there rises a dense white cloud which fills the vessels and concretes into minute glittering crystals of volatilized super-sulphat. After this rises a great quantity of sulphurous acid and water, the greater part of which condenses in the receiver, and with them a quantity of *azotic gas*, all of which continue till nothing remains in the retort. During the distillation the contents of the retort are always liquid, and when the process is over, the receiver contains sulphurous acid, water, and ammonia, and in the neck of the retort is a quantity of sublimed super-sulphat of ammonia.

In the above process several decompositions take place. At first a part of the ammonia separates from the salt leaving the latter with excess of acid; after which, as the heat is increased, part of the super-sulphat in the retort is totally decomposed, the ammonia is resolved into its elements, azot and hydrogen, the former of which passes off in a gaseous form, and the hydrogen unites with part of the oxygen of the sulphuric acid to form water, and the acid with a diminished quantity of oxygen becomes sulphurous acid. The entire products therefore are ammonia, water, sulphurous acid, together with some super-sulphat that has escaped compleat decomposition.

All the other ammoniacal salts suffer this decomposition of the alkali, totally or in part, when exposed to a high heat.

Sulphat of ammonia is decomposed by the fixed alkalies and by the alkaline earths. Its composition according to Kirwan, is 14.24 per cent. of ammonia, 54.66 of acid, and 31.1 of water.

Sulphat of Barytes.

The native sulphat has been already described under the article *Heavy Spar*, and it appears to agree very exactly in chemical composition with the artificial sulphat, for if any given weight of heavy spar be decomposed by a carbonated alkali, and the carbonated barytes thence arising be dissolved in muriatic acid, and again precipitated by sulphuric acid in the form of a sulphat, the weight of the latter very exactly corresponds with that of the native sulphat if pure, and if an equal degree of heat has been employed in the desiccation.

Sulphat of barytes is formed whenever any barytic salt comes in contact with sulphuric acid in any combination, and being perfectly insoluble in water, and in all acids, except the most concentrated, it precipitates totally and speedily in all common cases, and may be collected, edulcorated, and dried with great ease, and without risk of loss. It is then quite free from smell and taste.

Sulphat of barytes is the heaviest of all the earthy salts. It undergoes no change by being heated red-hot, without addition, except the loss of the water which it may contain. In a very strong fire and before the blow-pipe it melts into an opake milky globule.

This salt is perfectly unchanged by any exposure to air. None of the acids when at all dilute have any effect upon it, but if it is heated with concentrated sulphuric acid to the boiling point of the acid, it dissolves therein compleatly, forming a clear colourless dense fluid.[f] On dilution with water the sulphat of barytes again separates totally and unchanged. The sulphuric solution exposed to the air for some days deposits the sulphat of barytes in beautiful radiated crystals, and this is the only method in which it can be brought to crystallize by art. This is doubtless effected by the absorption of water from the atmosphere, which dilution being gradual allows the sulphat to be separated in a regular form.

No single agent, neither acid, nor alkali, nor earth, can separate the sulphuric acid from barytes except perhaps the fixed acids such as the arsenic and fluoric, in a very strong heat, but this sulphat is readily decomposed by double affinity by the carbonated fixed alkalies; and also by fusion with charcoal. In the former case the decomposition may be effected either by repeatedly boiling the sulphat in fine powder, with a solution of carbonat of potash and soda, or by mixing the sulphat with two or three times its weight of the dry carbonated alkali, and giving the mixture a moderate red heat (which need not be urged to fusion) for half an hour, and then lixiviating the saline mass.

In both instances a saline solution is formed, which consists of sulphat of potash or soda with some undecomposed alkaline carbonat, and an insoluble powder is obtained, which

[e] Hatchett, Phil. Transf. for 1796. p. 315.

[f] Withering, Phil. Transf. for 1784.

consists of carbonated barytes with any sulphat of barytes that may have escaped decomposition, and which may be readily separated by the nitric, muriatic, or acetic acids, which dissolve the carbonat and leave the sulphat.

In the other method, sulphat of barytes is decomposed by fusion with about a sixth of charcoal, and sulphuret of barytes is formed, from which the earth is then readily separated by nitric or any other acid.

Sulphat of barytes is also decomposed by fusion with muriat of lime.

All these methods are more fully described under the article *Barytes*. (p. 124.)

Though barytes or any of its soluble salts are highly poisonous, its sulphat has no obvious effect on the body when taken into the stomach.

The composition of sulphat of barytes has been very variously estimated. Kirwan, Klaproth, Black, and some other eminent chemists, reckon it to be composed of about two parts of barytes and one of sulphuric acid, or 33.3 per cent. of acid and 66.6 of earth, when heated long enough to expell all the adhering moisture. On the other hand Mr. Chenevix estimates only 23.5 per cent. of acid and 76.5 of barytes. As the authorities on each side are of the highest respectability, and as the establishment of this point is of more importance than perhaps of any other compound, on account of the frequency with which it is resorted to in chemical operations, it will be right to give the particulars of each mode of estimation, which are in many respects essentially different.

Dr. Withering in his analysis of the native carbonat of barytes dissolved 100 grains of this substance in muriatic acid, then decomposed it by dropping in sulphuric acid till no more precipitate ensued, and the latter, after edulcoration and ignition for half an hour in a *red heat*, weighed 117 grains. In another experiment, 50 grs. of the carbonat gave 58.4 grs. of the sulphat, which closely corresponds with the former. Now he had before found that 100 grains of the carbonat, previously dried in a red heat, and then dissolved in muriatic acid, lost 21 grs. by effervescence, which was therefore carbonic acid, and contained 78.6 grs. of pure barytes. Hence as 100 grs. of the carbonat give 117 of the ignited sulphat it may be concluded that these 117 parts are composed of 78.6 of barytes and 38.4 of acid, or, that 100 parts of the sulphat of barytes consist of about 67.2 of barytes, and 32.8 of acid.

The experiments of Klaproth,[g] very closely agree with those above mentioned. This accurate chemist found by analysis, that 100 grains of witherite, or native carbonat of barytes, contained 78 of barytes, and that the same quantity of it dissolved in muriatic acid, and precipitated by the sulphuric gave 120.5 grs. of sulphat of barytes *dried in air*, which may be reckoned as equal to 117.2 grs. of the same when *fully ignited*; for he says in another place,[h] that 185 grs. of sulphat dried in air were reduced to 180 by ignition. This estimation therefore would give 66.55 of barytes, and 33.55 of sulphuric acid in 100 of the dry sulphat.

Nearly the same quantity of acid also is found indirectly by decomposing an alkaline sulphat by a barytic solution. Dr. Black found in his analysis of the Geyser waters, that 100 grs. of fully dried Glauber's salt formed 170 grs. of dry sulphat of barytes; and Klaproth[i] also found the same quantity of Glauber's salt to produce 168 grains of sulphat of barytes. Now by Mr. Kirwan's experiments,[k] 100 grs. of dry Glauber's salt contain 56.08 of real sulphuric acid, whence the proportion in 100 of sulphat of barytes would be 32.98 in Dr. Black's experiment, and 33.38 in Klaproth's. The Glauber's salt also that Klaproth employed contained in 132.5 grains all the dry sulphuric acid of 95 grs. of liquid acid of 1.85 sp. gr. which by Mr. Kirwan's estimation is 77.18 grs. of real acid, and therefore amounts to 56.9 grs. in 100 of sulphat of soda, a number sufficiently near to 56.08 to confirm the general accuracy of the experiment.

From all these experiments therefore we are led to conclude that dry sulphat of barytes contains very nearly two-thirds of barytes, and one-third of acid, or 66.6 per cent. of the former, and 33.3 of the latter.

On the other hand the experiments of Mr. Chenevix[l] on this subject include two objects, one to ascertain the quantity of sulphur in sulphuric acid, and the other to determine the composition of the sulphats of barytes and lime. They were as follows: 100 parts of sulphur were put into a retort with nitric acid, and a receiver with a Woulfe's apparatus was luted on. The acid was repeatedly distilled off the sulphur till the whole was dissolved, and converted into sulphuric acid, and the nitrous gas generated in the process was passed through water to absorb any sulphurous acid if gene-

[g] Analyt. Essays, vol. i. p. 232—237. [h] Ibid. p. 376. [i] Ibid. p 282. [k] Addit. Observ. on Mineral Acids.

[l] Irish Acad. Trans. for 1802, or Phil. Mag. vol. 5.

rated, but none of this was found. All the liquors in the apparatus were united, and nitrat of barytes was added as long as any precipitate appeared, which was therefore sulphat of barytes, and amounted when dry to 694 grs. Two other experiments gave nearly the same results, whence the author concludes the quantity of sulphur in 100 parts of sulphat of barytes to be 14.5 grs.

In the next place some pure lime was prepared by saturating muriatic acid with white marble, precipitating the lime as a carbonat by carbonated potash, and fully calcining the carbonat of lime in a platina crucible, in a violent heat, till the weight no longer diminished. Of this lime, 100 grains were dissolved in dilute muriatic acid in a platina crucible, and then sufficient sulphuric acid was added which precipitated sulphat of lime. The whole contents of the crucible were evaporated to dryness, then raised to such a temperature as would expell every thing but the combined sulphuric acid. The increase of weight thus obtained was 76 grs. whence the author concludes 176 parts of dry sulphat of lime to contain 76 of real sulphuric acid, so that this salt will then consist of 57 per cent. of lime and 43 of acid. Hence, by knowing the ratio that sulphat of barytes bears to sulphat of lime, the quantity of sulphur in sulphuric acid may be ascertained. For this purpose 100 grs. of the same dried sulphat of lime (at 43 per cent. of acid) were attempted to be dissolved in water alone, but finding that an inconvenient bulk of fluid would be required in this way, Mr. C. first added some oxalic acid to the sulphat, and then a little muriatic acid, which effected a compleat solution in a moderate quantity of fluid.

The solution therefore contained oxalat of lime, probably with a little super-sulphat, both of which were dissolved in muriatic acid.

Into this liquor muriat of barytes was poured as long as any precipitate fell down, and the liquor was heated for a short time to keep in solution any oxalat of barytes which would be formed, and which is easily soluble in an excess of acid. The weight of the sulphat of barytes was (on the average of three experiments) 183 grs. which therefore, contain as much acid as 100 grs. of the sulphat of lime employed, or 43 grs. and hence 100 parts of sulphat of barytes will contain 23.5 of acid. But by the first experiment, 100 parts of sulphat of barytes were formed by the acidification of 14.5 grs. of sulphur, and hence the 23.5 parts of sulphuric acid are estimated to be composed of 14.5 of sulphur and 9. of oxygen, so that 100 parts of dry sulphuric acid must consist of 61.5 of sulphur and 38.5 of oxygen. Also, if sulphat of barytes contains only 23.5 per cent. of acid, the whole of the remainder, or 76.5 must be barytes

To recapitulate the results of these experiments —

Sulphuric acid is composed of

61.5	Sulphur
38.5	Oxygen
100.0	

Sulphat of lime, perfectly desiccated, is composed of

57.	Lime
43.	Sulphuric acid
100.	

Sulphat of barytes, perfectly desiccated, is composed of

		76.5	Barytes
Sulphur	14.5	23.5	Sulphuric acid
Oxygen	9.0		
		100.0	

100 parts of sulphat of lime contain the same quantity of acid as 183 parts of sulphat of barytes.

The disagreement between the experiments of Mr. Chenevix and those of Klaproth, Withering, and other chemists already mentioned, is much too great to be accounted for from slight variations in desiccation, &c. and we must acknowledge they are unaccountable. Some observations may be made on this subject.

First, as to the proportion of barytes in the sulphat estimated by Mr. C. This able chemist infers it from the quantity of acid produced, and attempts to account for the difference between his and former calculations, by observing that "at the time when the experiments "were made that determined the proportion of "33 per cent. of acid in sulphat of barytes it "was not known that we had never obtained "barytes pure, and that a considerable portion "of carbonic acid resisted the action of every "degree of heat that had been applied to car- "bonat of barytes," &c.

But the experiments that determined the above proportion of 33 per cent. were made

by decomposing the carbonat, not by heat, but by an acid, and the loss of about 22 per cent. of carbonic acid by effervescence was confirmed in Klaproth's experiments by many unexceptionable processes. If therefore, as we have before mentioned, 100 parts of the pure carbonat lose nearly 22 of carbonic acid by effervescence, and produce 117 of the sulphat (which is a simple and apparently unexceptionable experiment) the quantity of 76.5 per cent. of barytes in the sulphat must be largely overrated; for if 100 of the sulphat contain 76.5, 117 will contain 89.5 of barytes, which is obviously incompatible with the other experiments, as the 100 parts of carbonat could not contain more earth than 78 at the utmost, when it lost 22 by effervescence.

Mr. Chenevix produced 694 of sulphat of barytes by acidifying 100 grs. of sulphur with nitric acid, and precipitating all the liquors by nitrat of barytes; which is in the proportion of 14.5 of sulphur in 100 of the sulphat. But if 100 of sulphat of barytes contain 66.6 of earth and 33.3 of acid, the composition of sulphuric acid would be as 14.5 of sulphur to 18.8 of oxygen, which is double the highest estimation of oxygen, and obviously impossible. Can a quantity of nearly insoluble nitrat have mixed with the sulphat and increased its weight?

In Mr. Chenevix's next experiment the 43 parts of sulphuric acid contained in 100 of sulphat of lime, produced 183 of sulphat of barytes. According to Klaproth's analysis of this latter sulphat 43 parts of acid should only have produced three times as much sulphat of barytes, or 129 parts. The method employed by Mr. C. was rendered complex by the introduction of oxalic acid, yet it does not appear that it would involve any material source of error. But on the other hand, Klaproth[m] estimates that 220 of sulphat of barytes are equivalent in acid to 160 of sulphat of lime, whence 100 of the latter would yield by decomposition 137 of sulphat of barytes. It should also be observed that Mr. Chenevix makes a much lower estimaation of the quantity of sulphuric acid in sulphat of lime than Kirwan, Klaproth, and other chemists do; for by Mr. Chenevix, 57 of lime and 43 of acid constitute 100 of the sulphat, but by the other estimation 100 parts of perfectly dry selenite, contain about 40 of lime and 60 of acid.

The disagreement of these experiments performed by chemists of acknowledged skill and fidelity, might lead to the supposition of there being more than one species of artificial sulphat of barytes, with different proportions of acid and earth, but further experiments are required to determine this point.

A most unexceptionable method of ascertaining the quantity of barytes would be the following: dissolve some of the purest tabular crystals of muriated barytes in water, decompose the solution by carbonated ammonia, wash the precipitated carbonated barytes, and dry it for half an hour in a low red heat. Take a given quantity of this carbonat, saturate it with muriatic acid, and note the loss of carbonic acid, decompose the solution by sulphat of soda, edulcorate the barytic sulphat, and dry it in a low red heat for half an hour, and weigh it. Then take another equal or aliquot portion of the carbonat of barytes, dissolve it in the purest nitric acid, evaporate the solution to dryness, and gradually ignite the nitrat in a clean platina crucible till all the acid is decomposed and driven off, and the pure barytes alone is left.

The results of these experiments compared together, would give as accurately as can well be done, the quantity of carbonic acid, and of barytes in the carbonat, and of barytes in the sulphat.

Sulphat of Lime. *Selenite. Gypsum.*

Under the article *Gypsum* the different species of the native sulphat of lime are described. To this it may be added that this salt is most extensively diffused over the earth, being found in small quantity in almost every common spring water to which it gives (in common with other earthy salts) the properties of hardness or harshness to the feel, and of curdling soap.

Sulphat of lime when taken into the mouth in substance is almost entirely destitute of taste, owing to its very difficult solubility. It requires for solution about 500 parts of cold water, and somewhat less of boiling water, so that it is partly deposited from the hot saturated solution on standing for some hours. Though the quantity of sulphat of lime in solution in pure water is so small, each of its ingredients may be formed into still less soluble salts, and a precipitate will appear on the addition either of oxalic acid which abstracts the lime, or of a barytic salt which unites with the acid.

Sulphat of lime is rendered much more soluble in water by the addition of any acid, all of which (the oxalic excepted) simply dissolve

[m] Vol. i. p. 168.

[a] Kirwan's Addit. Obs.

without decomposing it unless the quantity of acid be very large.

On evaporating any of the solutions of selenite in acids, and allowing the solution to cool when highly concentrated, this salt separates in long transparent crystals, which is a very common form for it to occur in chemical analyses. It is then distinguished by its want of taste, its difficult solubility when removed into pure water, and by its affording a precipitate with the oxalic and barytic salts. When a liquor containing selenite is rapidly evaporated, this salt separates as a brittle shining pellicle.

When the crystallized sulphat of lime, native or artificial, is calcined in a red heat, it splits, and falls into a mealy powder by the loss of its water of crystallization. This forms the plaster of Paris so much employed in modelling and cements, as it has the property when mixed with water to the consistence of a thin paste, of solidifying in a few minutes, and becoming a hard brittle mass.

Selenite, like all the other sulphats, is insoluble in alcohol, and hence this fluid is a very useful test to detect the presence of selenite in any watery solution, and to separate it without decomposition. Mr. Kirwan* found the power of this test to be so extensive that selenite may be compleatly precipitated from water that contains it in the proportion of $\frac{1}{1000}$, or even less, by any spirit of wine whose specific gravity is below 0.850. Hence much advantage may be made of alcohol in analyses of compounds that contain this salt.

Sulphat of lime is decomposed by the fixed alkalies, by lime, and by barytes, especially in a boiling heat, and still more readily by the alkaline carbonats. For this purpose reduce the sulphat to fine powder and boil it for a quarter or half an hour, with twice its weight of dry carbonat of potash or soda dissolved in water, and a compleat decomposition will be effected, the liquor will contain sulphat of potash or soda, and at the bottom will be the lime of the selenite, fully carbonated, from which the pure lime may be procured by compleat calcination in a platina crucible, or the proportion of lime may be estimated from the known constituent parts of the artificial carbonat, which, when dried and ignited, contains 55 per cent. of lime.

Sulphat of lime when exposed to a very intense heat melts into an opake white vitreous mass. When heated with charcoal, it is partially and imperfectly decomposed, and some sulphuret is formed.

The composition of sulphat of lime is given with some variety, by different chemists.

Mr. Kirwan found that 450 grs. of a dilute sulphuric acid (composed of 225 grs. of strong acid of 1.5654 sp. gr. at 60° mixed with 225 grs. of water) saturated 152 grs. of marble, which contained 83.6 grs. of lime. The above quantity of dilute acid contained 119.5 of *real acid* (for the explanation of which see the article Sulphuric Acid) and consequently the acid and lime are to each other as 119.54 : 83.6 or as 58.84 of acid to 41.15 of lime. But it is scarcely possible to obtain these quantities from 100 parts of selenite, unless after very long and violent ignition, on account of the obstinacy with which water adheres to the salt. This circumstance too throws some difficulty in the analysis of this salt, for if 100 parts, for example, be merely ignited for a short time, and the lime separated accurately, if the entire weight remaining to make up the 100 parts be considered as real acid, it would give too high a proportion of the latter, since selenite thus dried generally contains at least 5 or 6 per cent. of water.

Thus Klaproth obtained 26.5 grs. of ignited carbonat of lime from 40 grs. of ignited selenite, which would be equivalent to 36.87 of pure lime from 100 of the selenite; but if all the 63.13 remaining were considered as real acid, it would probably make it much too high.

The estimation given by Mr. Chenevix of the proportions of sulphuric acid and lime in the sulphat very strongly ignited, and the mode of making the experiment, have been already mentioned in the preceding article of *Sulphat of Barytes*. Dr. Thomson,[p] on repeating Mr. C's experiment obtained widely differing results, being 56 of acid and 42 of lime, whereas, Mr. C. obtained 43 of acid and 57 of lime. As Dr. Thomson's experiment much more closely coincides with those of Kirwan, Klaproth, Bergman, and Wenzel, we cannot help considering it as more correct, or at least as more approaching to the point of mutual saturation of the acid and base. From all that has been done, however, it is clear that when this sulphat occurs in chemical analysis it is not safe to estimate its composition from any assumed proportions, but it should be decomposed by boiling with an alkali in the way already mentioned, by which the quantity of lime may be

* On Mineral Acids.

[p] System of Chemistry, vol ii. p 355.

ascertained; and if that of the sulphuric acid be wanted, it must be obtained by converting it to a sulphat of barytes, having previously saturated the excess of alkali by muriatic acid.

There does not appear to be any proper *supersulphat* of lime, an excess of acid only rendering the sulphat more soluble, and it crystallizes from its acid solution in its common neutral state.

SULPHAT OF STRONTIAN.

This salt has been found native in England, near Bristol; in Pennsylvania; and more lately near Paris. It has already been described under the article *Cœlestine*.

Sulphat of strontian is a salt without taste and smell. It is nearly insoluble in water, but not absolutely so, for Klaproth found that a pound of water boiled on a quantity of this sulphat dissolved about 3 grains. It is not decomposed by any single acid; but barytes, alone or in combination, takes from it its acid, with which barytes has the greater affinity. Sulphat of strontian is also decomposed by the carbonated fixed alkalies, and with much more ease in the moist way than the sulphat of barytes. Sulphat of strontian, like the barytic sulphat, is readily soluble in sulphuric acid, and precipitable thence by dilution with water. This salt is decomposed by fusion with charcoal into a sulphuret.

The analysis of the native sulphat has been undertaken by Klaproth,[q] by Vauquelin,[r] and by Mr. Clayfield the discoverer of it in this country,[s] and the results of these chemists have a very close agreement.

The method to be followed in these analyses is very simple. Reduce a given quantity of it to fine powder, digest it in a warm temperature with a few ounces of dilute muriatic acid, which will separate any iron, lime, or sulphat of lime which it may contain, but will not touch the sulphat of strontian; then boil the insoluble residue for an hour with thrice its weight of very pure carbonat of potash dissolved in water, which will effect a compleat decomposition, the sulphuric acid of the salt will remain in solution with the potash, and a bulky white powder will subside which is carbonat of strontian. The quantity of sulphuric acid is to be ascertained by first super-saturating the solution with muriatic acid, and then adding muriat or acetite of barytes as long as any precipitate falls down, which is barytic sulphat, and should be washed, dried, ignited, and weighed. The carbonat of strontian remaining may be immediately washed, dried, and ignited, and from its weight that of the strontian may be inferred; but to be certain that all the sulphat of strontian has been decomposed, it will be better to redissolve the carbonat in dilute nitric or muriatic acid (by which any undecomposed sulphat will be left behind) and precipitate it by carbonated ammonia at a boiling heat, after which the carbonated earth may be dried. If any admixture of sulphated barytes is suspected, which is seldom the case, proceed as above, but instead of finally decomposing the muriatic solution of the earth by carbonated ammonia, evaporate it to the crystallizing point, when, after standing for a time, the *muriat of barytes* will appear in its proper form of white opake tabular crystals, whereas the *muriat of strontian* separates in needled crystals, which latter may be further distinguished by giving a red colour to the flame of alcohol.

With regard to the results of the different analyses, Klaproth found that 100 grs. of the sulphat decomposed in the manner above-mentioned, produced 124 grs. of ignited sulphat of barytes, and 82 grs. of carbonated strontian. The sulphuric acid of the former he reckons as a third of the weight, or about 42 grs.; and the pure strontian of the latter at 58 grs. having found by former experiments that 100 grs. of ignited carbonat of strontian lost 30 grs. of carbonic acid by effervescence, and that the remaining 70 per cent. were (to a trifling residue) pure strontian.

A hundred parts of pure sulphat of strontian therefore will contain according to this eminent chemist, nearly,

Real sulphuric acid	—	42 grs.
Strontian — —	—	58
		100.

The analysis of Vauquelin is so far imperfect that it only goes to ascertain the quantity of strontian in the sulphat. By his experiments 167 parts of the sulphat gave 129 parts of the carbonat, which (following Klaproth's proportions) would give 54 of strontian in 100 of the sulphat.

Lastly, Mr. Clayfield, whose analysis seems conducted with care and skill, and who ascertained both the quantity of earth and of acid, gives the composition of this sulphat almost exactly the same as that of Klaproth. He also

[q] Anal. Essays. [r] Journ. des Mines, tom. 7, No. 37. [s] Nicholson's Journal, 4to. vol. 3, p. 337.

asserts that the artificial sulphat contains 2 per cent. more acid than the natural.

SULPHAT OF MAGNESIA. *Epsom Salt. Bitter Purging Salt.*

This useful salt is occasionally found native, but by far the greater part is artificially prepared.

The native salt when solid is met with almost invariably in the form of fine capillary crystals, on the surface of decomposing schistus, often in coal-pits, and not unfrequently efflorescing on the surface of the soil. A very pure sulphat of this kind is described under the article BITTER SALT *(which see)* and was found in the mercury mines of Idria where it is known under the name of *Haarsalz*, and was mistaken for plumose alum till Klaproth detected its real nature.

Fontana mentions[t] a large quantity of this salt found in the quarries of gypsum in Piedmont efflorescing on the surface of the gypsum (particularly in those that are the most exposed to the sun,) which is brushed off from time to time, and when dissolved in water and crystallized is sold by the peasants.

Proust[u] also relates that this salt abounds so much in many parts of Spain, that in Andalusia large tracts are covered with an efflorescence of it after floods; and in most of the houses of Madrid, the foundation and lower walls are covered with this salt, which arises from the decomposition of the mortar, to the great detriment of the buildings.

It is not unfrequent to meet with the same salt in this country, forming a fine hair-like saline covering to the walls of damp cellars, or new buildings. An efflorescence of this kind is noticed by Dr. Bostock[v] on the walls of a new house near Liverpool, which was very pure sulphat of magnesia; and a similar production of this salt is mentioned by Mr. Gregor,[w] on the surface of a wooden frame used to sift coal-ashes, which latter on analysis were found to contain gypsum along with sulphat of magnesia. In many of these instances the sulphat of magnesia appears to arise from a decomposition of sulphat of lime by magnesia, but the precise mode in which this apparent contradiction to the known order of affinities is brought about, is not very apparent. In other cases the pyrites commonly contained in coal appears a principal agent in the production of this salt, for Mr. Gregor obtained it in abundance by calcining for an hour a mixture of about two parts of pyrites with one of steatite, and after long exposure to air, lixiviating the calcined mass.

It is probable that many of the natural saline efflorescences which have been supposed to be native saltpetre, may contain sulphat of magnesia.

Another source of this salt is in certain saline springs, and it is from these that our first knowledge of it originated.

It was first discovered at Epsom in Surrey, by Dr. Grew, in the year 1675, in a mineral water, to which it gave considerable celebrity, and the salt itself was extracted by boiling, and was sold at a high price as Epsom salt. The same salt was sometime afterwards found in a well at Shooter's Hill in Kent, in the year 1700, which was also extracted by boiling down, and was sold as Epsom Salt.

A few years afterwards it was found by some chemists that the same salt could be prepared from the *bittern* or mother water of sea-water, after all the muriat of soda had been extracted in the usual method, and which used to be thrown away. This process was long kept as a lucrative secret in the hands of a few salt-makers, and the sulphat of magnesia made at the brine works at Portsmouth and Lymington being afforded much cheaper than could be done by the evaporation of the mineral waters of Epsom or Shooter's Hill, the latter gradually fell into disuse, and for many years almost all the vitriolated magnesia used in this country has been prepared at the salt works at Lymington.

This salt was long considered as peculiar to this country, and large quantities were exported into other parts of Europe, and sold under the name of *English or Epsom Salt*. It was afterwards discovered in the mineral water of Seydschutz or Sedlitz in Bohemia, whence it also obtained the name of this water, the celebrated Hoffman having shewn its identity with the true Epsom salt. Sulphat of magnesia was long confounded with sulphat of soda, and though sufficient marks of distinction were given by many practical chemists, the true nature of the Epsom salt was not fully understood till Dr. Black, in 1755, shewed, in the most convincing manner, that it consisted of magnesia, combined with the vitriolic acid, and obtained the magnesia from it by means of an alkali.

This confusion of the two salts was further promoted by a fraud commonly practised on the Continent (where the English or Epsom salt was

[t] Journ. de Phys. tom. 33, p. 312. [u] Ibid. tom 32, p. 247. [v] Phil. Journ. vol. 3. [w] Ibid. vol. 5.

fold at a high price) of substituting for it Glauber's salt, made by stirring a warm saturated solution of it till nearly cold, whereby it separated in small needled crystals, very closely resembling the form of the true Epsom salt. On the other hand, when Glauber's salt was the most in request in this country, the Epsom salt makers used to obtain the latter salt in large crystals imitating the sulphat of soda, by adding an excess of sulphuric acid, and probably by a slower evaporation. Both these salts were occasionally called in medicine *Sal Mirabile*, and as the medicinal effect was the same, this also further contributed to keep up the mistake. The distinction between the two is now known to be perfectly simple, for the addition of any carbonated fixed alkali will immediately render a solution of sulphat of magnesia turbid, but will not alter the transparency of sulphat of soda. The solution should be somewhat diluted.

The method of preparing sulphat of magnesia, from the bittern of sea-water, has been variously stated. It is strongly affirmed by some, that no addition is made to it, but that the whole process is merely that of evaporating the liquor to a very high point of concentration, and on cooling, the sulphat crystallizes, which is purified by a second solution and crystallization. On the other hand it is stated, (and, we must acknowledge, with much more probability) that sulphat of iron, or the mother water of vitriol, or sulphuric acid, in some form or other, is added to the bittern. If Bergman's analysis of sea-water is correct, this addition is necessary; for, according to this eminent chemist, sea-water contains, in the English wine pint, 186.5 grains of muriat of soda, 51 grs. of muriated magnesia, and 6 grs of sulphat of lime. Therefore, as during the evaporation only muriat of soda, with part of the sulphat of lime, are separated, the *bittern*, or residue after the salt has been chiefly extracted, must contain a large quantity of muriat of magnesia, some common salt, and only a very small portion of sulphat of lime; and, consequently, an addition of sulphuric acid, in some form or other, is required to decompose the magnesian muriat.

Sulphat of magnesia has a salt and bitter taste, followed, when taken in quantity, with a slightly sweetish flavour. The regular form of this salt is a four-sided prism, terminated by four-sided pyramids; but it is only obtained regular by the slow and insensible evaporation of a saturated solution. In general it is in the form of small white needled crystals, produced by the cooling of the hot saturated solution. The common sulphat is considerably deliquescent, but this is probably owing to the admixture of some muriat of magnesia or lime; for the large regular crystals of this sulphat are permanent in the air, and somewhat effloresce when the atmosphere is dry and warm.

This salt is extremely soluble in water. The precise degree of solubility in some measure depends on its purity: the pure salt dissolves in nearly its own weight of cold water, and by increasing the heat much more is taken up. The salt, when heated alone, melts in its own water of crystallization, of which it contains about 48 per cent,[*] after which it becomes a hard opake mass, which will bear a very strong heat without melting or parting with any of its acid; so that it is again equally resoluble in water. In a very intense heat, or before the blow-pipe, it melts into an opake mass.

This salt is not decomposed by any single acid. When the fixed alkalies are added to its solution, the magnesia is separated pure; but with the carbonated fixed alkalies, *carbonat of magnesia* is precipitated, as has been described under that article.

There does not appear to be any proper *super-sulphat of magnesia*, though the very large crystals of this salt are said to be made by slowly crystallizing the solution with excess of acid. If sulphuric acid is added to dry sulphat of magnesia, the whole of the excess of acid is volatilized at a low red heat, without difficulty.

The action of ammonia or its carbonat, on this salt, will be mentioned in the next article.

Sulphat of magnesia, when well crystallized, is estimated by Bergman to contain 19 per cent. of magnesia, 33 of real sulphuric acid, and 48 of water. Mr. Kirwan estimates that 100 parts of the salt, when perfectly dried at a strong heat, contain 36.68 of magnesia, and 63.32 of acid, which very closely agrees with the estimation of Bergman.

Sulphat of magnesia is frequently, in the course of chemical analysis, mixed with sulphat of lime, and often with sulphat of iron, and the separation of these salts is of importance in coming at accurate results. Several methods may be used. The following will separate the iron: if the mixture of these salts be in solution, and any casual excess of acid has been saturated, the addition of succinat of ammonia

[*] Bergman on Magnesia.

will precipitate the iron, and leave the earthy salts untouched; or else the mixed salts may be dried and calcined for an hour in a red heat, by which the acid will be expelled from the sulphat of iron, and the sulphat of lime also will be rendered scarcely soluble, whilst the affusion of cold water, and digestion for some hours, will completely dissolve out the sulphat of magnesia. If only the latter salt and sulphat of iron were present, the only insoluble residue will be the brown colcothar, or oxyd of iron, belonging to the sulphat, and from which the quantity of the latter may be estimated.

The Sulphats of lime and of magnesia may be separated in two methods. If the magnesian salt is very small in proportion to the other, the addition of perfectly caustic ammonia will separate the magnesia (though not totally) and leave the lime untouched, provided the mixture be kept for some hours in a well corked bottle, to exclude the carbonic acid of the atmosphere. But as it is more commonly required to separate sulphat of lime from a larger quantity of sulphat of magnesia, advantage is taken of the very difficult solubility of the former and the ready solubility of the latter. The mixed solutions therefore are to be concentrated highly by evaporation; when, after some hours repose, most of the sulphat of lime will separate alone, and may be removed. The solution may then be evaporated to dryness and strongly calcined, and then pulverized and digested with three or four times its weight of cold or lukewarm water, by which the whole of the magnesian sulphat will be dissolved, and what little sulphat of lime may remain after the first process, will remain untouched. The solution may then be boiled with carbonat of potash, to decompose the carbonat of magnesia, and the latter, when washed, dried, and ignited in a strong red heat till it is fully calcined, will be pure magnesia. We may add, that when calcined magnesia contains any lime, it may be easily detected by rubbing a quantity of it with some distilled water, putting the whole in a phial, and shaking the mixture frequently during digestion for a few hours. On subsidence, the clear liquor will be a *lime-water*, if any lime be contained in the magnesia, as may be discovered by its becoming turbid on blowing through it with the breath, or adding a few drops of a carbonated alkali; but if the magnesia be pure, the water will have dissolved nothing.

Sulphat of magnesia is largely used in medicine, both directly and for the preparation of *Magnesia* and its *Carbonat*, the methods of procuring which have been described under these articles.

AMMONIACO-MAGNESIAN SULPHAT.

When pure ammonia is added to sulphat of magnesia, a great part of the earth is precipitated, but the rest remains in solution, and, by evaporation, a triple salt, compounded of sulphuric acid, magnesia, and ammonia, is formed. This salt is also procured more speedily, and with less loss, by adding to a solution of sulphat of magnesia one of sulphat of ammonia, each somewhat concentrated. An abundant deposition of regular, transparent, shining crystals takes place immediately, which are the triple salt in question. The form of this salt is generally octohedral [y]: its taste is salt and bitter. When heated, it first melts in its own water of crystallization, after which it is decomposed, ammonia is first given out, then acidulous sulphat of ammonia rises, and simple sulphat of magnesia remains.

This triple salt is much less soluble in water than either of the sulphats of which it is formed, as is obvious by its precipitating on the addition of the two solutions. It is composed, according to Fourcroy, of 68 per cent. of sulphat of magnesia, and 32 of sulphat of ammonia.

SULPHAT OF ALUMINE.

The simple combination of sulphuric acid and alumine, was often produced in the researches of the various eminent chemists who have turned their attention to the analysis and manufacture of alum; but a more accurate knowledge of it is due to Vauquelin. Under the article *Alum*, we have fully detailed the many interesting experiments that have been made on this valuable salt, and given the proofs of the necessity of potash and ammonia to its composition.

Sulphat of alumine, therefore, differs from alum in not containing any alkali, and on this account it is scarcely crystallizable.

Sulphat of alumine is made by dissolving pure alumine in equally pure sulphuric acid, at a boiling heat, evaporating the solution to compleat dryness, and then re-dissolving the residue in water. In this state, if the previous desiccation has been compleat, an astringent solution is obtained, which is not sensibly acidulous, and by hasty evaporation only gives a saline magma; but when evaporated slowly, and with great care, it may be made to appear in the form of soft, flexible, shining crystalline plates. But if

[y] Fourcroy.

a few drops of potash, or any salt of potash, be added to the solution, the alkali unites to the sulphat of alumine, and almost immediately a quantity of (comparatively) large hard octohedral crystals of alum are deposited. The proportion of potash necessary to produce a sensible quantity of alum is so small, that all the common sulphuric acid of the shops will give it; and hence the pure sulphat of alumine must be made with rectified sulphuric acid, and very pure alumine.

Sulphat of alumine is infusible in any heat, but when strongly urged in the fire, it parts with its acid altogether.

An *Acidulous*, or *Super-sulphat of Alumine*, is formed by dissolving the latter salt in sulphuric acid. It is then crystallizable with still more difficulty, and the salt is sensibly acid and austere to the taste. It deposits crystals of alum still more readily on adding potash than the neutral sulphat does, as alum is naturally a salt with excess of acid.

The super-sulphat of alumine may be reduced to the neutral sulphat by long boiling with alumine, but with difficulty. Neither of these salts is used.

SULPHURIZED MURIATIC ACID.

Sulphur, when exposed to the long-continued action of oxymuriatic acid, is converted into sulphuric acid, as we have already mentioned; but when the oxygenation of the sulphur is not compleated, the result is a singular compound, the properties of which have hitherto been only examined by Dr. Thomson.[a] It is thus prepared: charge a retort with common salt and oxyd of manganese; annex to it a Woulfe's apparatus, with two or three bottles; put some dry flowers of sulphur into the first bottle, and into the next some carbonated potash, to absorb the superfluous acid: then pour into the retort some concentrated sulphuric acid, and oxymuriatic acid gas will be immediately liberated. After the sulphur has been for some time in contact with this gas, it will become moist and doughy, its colour will change to orange, by degrees it will become more and more soft, and at length will be resolved into a red fluid: as soon as this is effected, the process must be stopped.

The liquid thus obtained is perfectly clear, of a colour between scarlet and crimson, by reflected, and green by transmitted light; its specific gravity is = 1.62, and its weight is more than twice that of the sulphur employed. When first exposed to the air it smokes like the distilled muriat of tin, but after a time its fumes are not more copious than those from strong muriatic acid. It is very volatile at a moderate temperature. Its odour resembles that of sea-weed, but is much stronger, and it affects the eyes in the same manner as wood smoke does. Its taste is acid, hot and bitter. It changes paper stained with vegetable blues to red, but not very rapidly, unless water is added.

If a drop of sulphurized muriatic acid be let fall into a glass of water, the surface is immediately covered with a thin film of sulphur, and a greenish red globule falls to the bottom, which remains for some time like a drop of oil, but is at length converted into acid flakes, of a yellow colour, which are very ductile, even after long exposure to the air. A similar yellow matter is precipitated from the sulphurized muriatic acid, on the addition of a weak solution of potash: this matter is hot to the taste, and adheres to the finger like thick oil paint. By digestion in hot water it is converted into common sulphur, and the water becomes acidulous from the presence of muriatic and sulphuric acids. Solid muriat of barytes, whether crystallized or in fine powder, affords no precipitate with the entire sulphurized acid, whence it appears that it contains no sulphuric acid; but this latter makes its appearance whenever water is added: it is probable therefore that the whole of the sulphur, when combined with the muriatic acid, is in the state of oxyd, but the addition of water determines the whole of the oxygen to unite with part of the sulphur, converting it into sulphuric acid, while the remainder of the sulphur is deoxydated.

If this sulphurized acid is poured into warm nitric acid, a violent effervescence, accompanied by a kind of explosion, takes place; but if it is dropped very slowly into cold nitric acid, only a moderate effervescence takes place. Nitrous gas and oxymuriatic acid gas are evolved, and the sulphur is acidified.

Sulphurized muriatic acid, even when cold, dissolves phosphorus very readily; no effervescence happens, and the solution acquires a bright amber colour. If this solution is mixed with caustic potash, the whole mass becomes beautifully luminous, and sulphur in combination with phosphorus is precipitated.

When mixed with alcohol, a violent effervescence ensues, and ether is disengaged.

Nitric acid decomposes this sulphurized acid, without occasioning any precipitate. Sulphur-

[a] Nich. Journ. 8vo. vol. vi. p. 104.

ous acid appears incapable of decomposing it, but all the other acids throw down from it a quantity of sulphur. The fixed alkalies, when dry, produce with it a violent effervescence, and a considerable degree of heat. If ammoniacal gas is thrown into it, the vessel is soon filled with a purple vapour, and the liquor becomes solid, and of a deep red colour; but when mixed with water it speedily dissolves, and sulphur is precipitated. This singular substance has not yet been very exactly analyzed; indeed it appears to be by no means uniform in its composition: in one specimen Dr. Thomson found the relative proportions of muriatic acid and oxyd of sulphur to be as 44. of the latter to 35. of the former. In another specimen the proportions were 47.1 muriatic acid, 35.2 oxyd of sulphur, and 4. sulphuric acid. The oxyd of sulphur appears to be composed of 93.8 sulphur, and 6.2 oxygen.

SULPHUROUS ACID. *Acide Sulfureux.* Fr. *Schwefeligte Saure*, Germ.

The suffocating vapour that rises during the combustion of sulphur, is sulphurous acid, and although some of its most obvious properties must have been known from time immemorial, yet the first chemist who appears to have examined it with any attention was Stahl. This eminent philosopher named it *phlogisticated vitriolic acid*, because he considered it as differing from common vitriolic acid only in containing a larger proportion of phlogiston or the principle of inflammability: he also shewed that it might be combined with potash, by dipping a cloth in a solution of this alkali, and exposing it, while yet moist, to the vapour of burning sulphur. Scheele made some additions to our knowledge of this substance, which was still further extended by the important discoveries of Dr. Priestley. Next, Berthollet investigated the properties of this acid and its salts, with his accustomed sagacity. The accuracy of Vauquelin, in conjunction with Fourcroy, enlarged still further our acquaintance with this substance; and, finally, we are indebted to Dr. Thomson, for the best analysis of it that has yet been published, and for the discovery of some interesting facts, which had been overlooked or obscurely stated by preceding inquirers.

There are two ways of procuring sulphurous acid; namely, by the combustion of sulphur, or by the partial decomposition of sulphuric acid. The first of these methods, although apparently very simple, is in fact the most troublesome; for if the combustion is performed by atmospheric air, the newly-formed acid mixes with the residual azotic gas, from which it is incapable of being directly separated. If, on the other hand, oxygen gas is made use of, not only sulphurous but sulphuric acid is produced, and part of the oxygen remains mixed with the sulphurous acid gas. Hence it is that, for chemical experiment, this acid has always been procured by the decomposition of sulphuric acid.

Various substances have been employed for this purpose, such as wood, charcoal, oil, alcohol, and other vegetable substances and products: all these, however, are more or less objectionable, as both carbonic acid and gasseous oxyd of carbon are given out together with the sulphurous acid. Sulphur itself has been made use of, and the only objection is the slowness with which the acid is thus produced. Dr. Priestley first employed the metals, instead of the more compound combustibles. He found that iron and zinc, being metals so greedy of oxygen as to decompose water, were by no means so proper for this purpose as copper, silver, or mercury; since in the former case the acid was mixed more or less with hydrogen, proceeding, no doubt, from the decomposition of the water which common sulphuric acid contains.

Sulphurous acid gas is thus prepared: pour into a narrow necked glass retort two p rts, by weight, of concentrated sulphuric acid, and one of mercury; dip the beak of the retort under mercury, and then apply a lamp or a pan of charcoal: when the acid gets warm, it will begin to act on the mercury, and bubbles of gas will be disengaged: as soon as the common air of the vessel is driven out, and is succeeded by bubbles of white suffocating vapour, an inverted jar, filled with mercury, may be placed over the beak of the retort, and will thus be speedily filled with gas. This gas is sulphurous acid in its purest state, and exhibits the following properties. It is invisible, colourless, and elastic, like common air; it has an extremely pungent suffocating odour, and is incapable of supporting either combustion or animal life. Its specific gravity is about = 0 c025, or somewhat more than twice as great as that of atmospheric air. It is acerb and sour to the taste, reddens most blue vegetable juices, and, after a time, destroys the colour of many of them. It does not appear susceptible of any change by mere heat; but, according to an experiment by Monge and Clouet, if exposed at the same time to great pressure and a cold equal to 31° Fahr., it loses its elasticity, and assumes a liquid state. Water, by simple exposure to an atmosphere of

this gas, without agitation or extraordinary pressure, absorbs, according to Priestley,[b] about 44 times its bulk, or $\frac{11}{100}$ of its weight; and according to Thomson, at 61° Fahr. 33 times its bulk, or $\frac{8.25}{100}$ of its weight; but if water be saturated with this gas, by means of a Woulfe's apparatus, the bottles of which are surrounded with ice, it will be found to have taken up, according to Vauquelin,[c] about $\frac{15}{100}$ of its weight. The specific gravity of this liquid acid is stated by Berthollet at 1.04, and by Vauquelin at 1.02; by Thomson at 1.05 at 68°.

Oxygen gas appears to have no action on sulphurous acid gas, when both the ingredients are dry; but if to a mixture of one part of the former and two of the latter, there be added a very little water, a sudden diminution of bulk will at first take place, owing to the absorption of part of the acid gas by the water; after which a further gradual absorption happens, in consequence of an actual combination going on between the two gasses, by which sulphuric acid is formed and part of the oxygen gas disappears. It is asserted by Fourcroy, that if a mixture of oxygen and sulphurous acid gasses are passed through a red hot tube, sulphuric acid is formed by their combination: in this case, however, it is probable that the gasses were previously saturated with water; for it is perfectly well ascertained, that during the distillation at a high red heat of calcined sulphat of iron, there comes over, besides sulphuric acid, a mixture of sulphurous acid and oxygen gas, which may be readily separated from each other by means of a dilute alkaline solution, which detains the former, but allows the latter to pass through unaltered.

Oxymuriatic acid gas is readily decomposed by sulphurous acid; the vessel becomes filled with white vapours, and a mixture of sulphuric and muriatic acids is the result.

Hydrogen gas and sulphurous acid exercise no action on each other at the common temperature, but if a mixture of three parts, by bulk, of the former, and one of the latter, are made to pass through a red hot glass tube, the sulphurous acid is totally decomposed, and the products are sulphur, water, and sometimes a little sulphuretted hydrogen.

Phosphorus, even when strongly heated in a glass tube, appears to have no action on sulphurous acid gas. Phosphuretted hydrogen, on the contrary, even at the common temperature, readily decomposes this acid; the mixture loses its state of elastic fluidity, a white vapour makes its appearance, and the sides of the vessel are lined with a mixture of sulphur and phosphorus. Sulphuretted hydrogen has a similar effect to phosphuretted hydrogen, and sulphur is precipitated from the decomposition both of the acid and of the inflammable gas.

Charcoal, at the common temperature, imbibes a considerable quantity of sulphurous acid gas, but appears to produce no material change upon it: at a red heat, however, the gas is decomposed, sulphur is deposited, and sulphuretted hydrogen is produced; the hydrogen, doubtless, originating from the water either of the acid gas or of the charcoal.

With camphor, sulphurous acid combines readily, and the result is a liquid, the properties of which have been but little investigated: this compound, when dropped into water, deposits again the camphor, which appears to have undergone scarcely any alteration.

Sulphuric acid, especially at a low temperature, absorbs a large proportion of sulphurous acid gas: the combination soon becomes solid, and in this state it has but little odour; but if a portion be laid on a piece of glass and exposed to the air, it presently resolves into a liquid, at the same time disengaging, with a very visible effervescence, the greatest part of the sulphurous gas. Strong and colourless nitric acid, by being impregnated with sulphurous acid gas, acquires a deep orange tinge, and nitrous gas is disengaged; the sulphurous being at the same time converted into sulphuric acid.

Water, when saturated with sulphurous gas, forms the liquid sulphurous acid: it is best prepared in a Woulfe's apparatus, with two or more bottles, into the first of which should be put a little water, to take up the sulphuric acid with which the gas is generally more or less mixed, while the purified sulphurous acid is absorbed by the water in the second and succeeding bottles. This liquid acid absorbs oxygen from the air, and is gradually converted into sulphuric acid. But if a little of it is confined in a glass tube, hermetically sealed and exposed to the common heat of a sand bath for a few weeks, the inside of the tube will be observed to be lined by degrees with minute crystals: after a time the deposition of crystals will cease: if then the end of the tube be broken off under mercury, this latter fluid will rise in the tube, shewing that a portion of the air has disappeared, and the residue, on examination, will be found to be wholly deprived of oxygen: the liquid which was pure sulphurous

[b] Experim. methodized, vol. ii. p. 318.

[c] Ann. de Chim. vol. xxiv. p. 237.

acid, will be converted, for the most part, into sulphuric, and the crystals are sulphur.[d] Hence it appears, that by the long continuance of heat, the oxygen of the liquid sulphurous acid quits one part of its base in order to form sulphuric acid with the remainder.

Sulphurous acid combines, either directly or by compound affinity, with the different salifiable bases, forming a genus of salts, which have obtained the name of *Sulphites*.

For an account of such of the metallic sulphites as are known, we refer the reader to the respective metals: there are, however, two or three general observations on the subject, for which the chemical world is indebted to Berthollet, which may not improperly be introduced here. Those metals that have a strong affinity, both for oxygen and sulphur, such as iron and tin, if digested with liquid sulphurous acid, furnish themselves with the requisite proportion of oxygen, by decomposing not the water but the acid; hence there is no disengagement of hydrogen gas, but one portion of the metal decomposes part of the acid, and after being thus oxydized, combines with the remainder of the acid and a little sulphur, while the rest of the sulphur produced by the decomposed portion of acid, combines with the remainder of the metal: hence there is produced both a sulphite and sulphuret. Zinc, on the contrary, though in its affinity for oxygen it is equal to iron, yet being greatly inferior in its attraction for sulphur, decomposes the water of the sulphurous acid rather than the acid itself; hence, during its solution, hydrogen gas is given out, and there is no appearance of any sulphur.

Those metals whose affinity for oxygen is but weak, as lead, mercury, and copper, are not acted on by sulphurous acid.

Some remarkable circumstances also occur, with regard to the action of metallic oxyds on this acid: some oxyds simply combine with the acid into a sulphite; others, as the black oxyd of manganese, give out a portion of oxygen to the acid, converting it totally, or in part, to sulphuric. Hence there is produced a sulphat, either mixed or not with a sulphite.

The only trust-worthy analysis of this acid which has yet been published, is Dr. Thomson's;[e] from which it appears that 82 parts of sulphuric acid, and 18 of sulphur, constitute 100 of sulphurous acid; according to which (if the analysis of sulphuric acid by Chenevix be assumed as the most authentic) this acid consists of

68	Sulphur
32	Oxygen
100.	

The order of the affinities of sulphurous acid, as far as it has been ascertained, is the following: barytes, lime, potash, soda, magnesia, ammonia, and alumine. It is separable in the form of gas from its earthy and alkaline bases, by the sulphuric, muriatic, phosphoric, and tartaric acids.

Sulphurous acid, or to speak more correctly the fumes of burning sulphur, is employed to discharge the natural yellow tinge from white woollen cloth, and to restore silk that has grown yellow by long wearing, to its original whiteness. It is also used to check the fermentation of vinous liquors.

SULPHITE OF POTASH.[f]

The most convenient method of preparing this salt is to connect a retort, charged with sulphuric acid and mercury, with a Woulfe's apparatus of two bottles, the former of them containing a little water, and the latter about two-thirds filled with a solution of crystallized carbonat of potash, in thrice its weight of water. The retort being heated, sulphurous acid gas is produced, which passing through the water in the first bottle, is thereby purified from any contamination of sulphuric acid, and then enters the alkaline solution in the next bottle, by which it is rapidly absorbed, carbonic acid gas escaping in bubbles at the same time. When the effervescence has ceased, and the sulphurous acid is no longer taken up by the liquor, the process is finished, and the liquor, as it cools, generally deposits crystals, if the above proportions of alkali and water have been observed.

Sulphite of potash thus prepared, is a transparent salt, sometimes colourless, but often with a slight yellowish tinge. It crystallizes either in the form of lengthened rhomboidal plates or divergent needles. To the taste it is pungent and sulphurous; its specific gravity is = 1.58: it is readily soluble in its own weight of water at the common temperature, and in a much smaller quantity of boiling water. If this solution is exposed to the air, it becomes covered in a short time with a crystalline pellicle; when this falls to the bottom, it is succeeded by

[d] Priestley. [e] Nich. Journ. 8vo. vol. vi. p. 95. [f] An de Chim. vol. xxiv. p. 254. Nich. Journ. vi. p. 94.

another, and ſo on till the whole is converted into ſulphat of potaſh. If oxygen gas is employed in the above experiment, inſtead of atmoſpheric air, the oxygenation of the ſalt takes place much more rapidly, with a very evident abſorption of the gas. By expoſure to a temperature of about 300° Fr. ſulphite of potaſh loſes about two per cent. which appears to be water. When heated in a retort, it firſt decrepitates, and is converted into an opake white powder, and on an increaſe of temperature loſes about 22 per cent. of which 15 are ſulphurous acid gas, 5 are ſulphur, and 2 water; the ſalt that remains behind is ſulphat of potaſh, with a ſlight exceſs of alkali. If, inſtead of being heated in a retort, it is rapidly ignited in a platina crucible, after the decrepitation has ceaſed, a blue flame makes its appearance, occaſioned by the combuſtion of the ſulphur, after which the ſalt is found to have loſt 22 per cent. as before. The component parts of this ſalt, according to an analyſis by Dr. Thomſon, are

43.5	Sulphurous acid
54.5	Potaſh
2.0	Water
100.0	

This, as well as the other ſulphites, is moſt conveniently analyſed in the following manner: firſt aſſay the ſolution with ſulphite of barytes, to aſcertain whether any mixture of ſulphat is preſent, and having thus got rid of the ſulphuric acid, add nitrat of lead as long as any precipitate falls down. The ſulphite of lead thus obtained, conſiſts, according to Dr. Thomſon, of 23 per cent. ſulphurous acid, and 75 yellow oxyd of lead.

Nitric acid converts this ſalt into ſulphat of potaſh; oxymuriatic acid produces a ſimilar effect, but at the ſame time drives off a portion of ſulphurous acid, ſo that the reſulting ſulphat is mixed with a little muriat.

It is alſo converted into ſulphat by the oxyds of gold, ſilver, mercury, the red oxyd of lead, and the black oxyd of manganeſe.

It is decompoſed, by compound affinity, by all the earthy and alkaline ſulphats, except ſulphat of barytes; by the nitrats, with the exception of nitrat of ammonia; by the muriats, with the exception of muriat of alumine; by the phoſphats of ſoda, ammonia, alumine, and glycine; by the fluats of ſoda, ammonia, barytes, ſtrontian, and magneſia; by carbonat of ſoda; and by all metallic ſalts except the carbonats. It has not been applied to any uſe.

Sulphite of Soda.

This ſalt is prepared from carbonat of ſoda, in the ſame manner as ſulphite of potaſh is from carbonated potaſh. It forms at firſt a confuſedly cryſtallized maſs, which by ſubſequent ſolution in hot water affords, on cooling, very regular diſtinct cryſtals, in the form of compreſſed tetrahedral priſms, with dihedral ſummits. Its ſpecific gravity is = 2.95. To the taſte it is cooling and ſulphurous. It is ſoluble in four times its weight of water, and in leſs than its own weight of boiling water. It effloreſces on expoſure to the air, and becomes covered with a white cruſt, but does not fall into powder as ſulphat of ſoda does; hence, although it is ſoon converted ſuperficially into ſulphat, yet the interior of the cryſtal remains for ſome time unaltered. When heated, it firſt melts in its water of cryſtallization, and on increaſing the temperature, undergoes changes preciſely analogous to thoſe already deſcribed in the preceding article. It is compoſed, according to Dr. Thomſon, of

31	Sulphurous acid
18	Soda
51	Water
100.	

It is decompoſed by the alkaline and earthy ſulphats, with the exception of the ſulphats of barytes and ſoda; by the earthy nitrats; by the ammoniacal and earthy muriats, phoſphats, and fluats; by the borat and carbonat of potaſh; and by moſt of the metallic ſalts. It has not yet been applied to any uſe.

Sulphite of Ammonia.

This ſalt is prepared in the manner deſcribed under ſulphite of potaſh, by ſaturating a ſolution of cauſtic ammonia with gaſſeous ſulphurous acid. It cryſtallizes either in hexahedral priſms, terminated by hexahedral pyramids, or in rhomboidal priſms, with obſcure trihedral ſummits. To the taſte it is cooling and pungent, with a ſulphurous flavour. It is ſoluble in its own weight of cold water, and in a ſmaller proportion of boiling water. By expoſure to the air it attracts moiſture, and is ſpeedily converted into ſulphat of ammonia; after which it becomes dry again. When heated, it ſlightly decrepitates, gives out a little water and ammonia, and then ſublimes in the ſtate of acidulous ſulphite. In its general properties it reſembles the other ſulphites, but combines with ſeveral of the ſalifiable baſes into triple ſalts.

It is decomposable by the sulphats of magnesia, alumine, and zircon; by the earthy nitrats and muriats; by the acidulous phosphat of lime; and the phosphats of alumine, glycine, and zircon; by the fluats of barytes, strontian, and magnesia; the borats of potash, soda, barytes, strontian and magnesia; and the carbonats of potash, soda, and barytes. It is not made any use of.

SULPHITE OF BARYTES.

This salt may be prepared, in the manner already mentioned, with either pure barytes or the carbonat reduced to a fine powder; or it may be obtained by compound affinity from a mixture of an alkaline sulphite with muriat of barytes. It is in the form of a white powder, insoluble in water and tasteless. By long exposure to the air, it is converted into sulphat of barytes. When strongly heated, sulphur is disengaged, and the residue becomes sulphat. But this salt, though insoluble in water, may without much difficulty, be dissolved in liquid sulphurous acid, and by slow evaporation, may be obtained in needle-form crystals, or truncated tetrahedrons. These crystals are sometimes transparent, but often opake; they are hard and nearly insipid, but at length leave a sulphurous flavour on the palate; they are rather sparingly soluble in water; and the solution is employed with advantage to purify the sulphites from any admixture of sulphat. The crystallized sulphite consists, according to Fourcroy, of

59.	Barytes
39.	Sulphurous acid
2.	Water
100.	

It is decomposed by the sulphats; by the alkaline phosphats; by the nitrat and muriat of strontian, and by the alkaline carbonats. It is not made any other use of than that already mentioned.

SULPHITE OF LIME.

This salt is prepared either with pure or carbonated lime, in the manner above described. It is in the form of a white powder, but by digestion in liquid sulphurous acid, it dissolves, and by slow cooling crystallizes in minute hexahedral prisms, with hexahedral summits. To the taste it is after some time slightly sulphurous. It is soluble in 800 parts of water. By exposure to heat the crystals fall into powder, and a little water comes over; at a red heat, a little sulphur is disengaged, and the residue is sulphat of lime. By long exposure to the air, it becomes somewhat efflorescent, and, after a considerable time, is changed into sulphat. Its component parts, according to Dr. Thomson, are

48.	Sulphurous acid
47.	Lime
5.	Water
100.	

It is decomposed by the alkaline and earthy phosphats; by the fluats and carbonats of barytes, strontian, and the alkalies; and by most of the metallic salts. It is made no use of.

SULPHITE OF MAGNESIA.

This salt is prepared with carbonated magnesia diffused in twice its weight of water, in the manner already described. It is in the form of powder, but by an additional portion of sulphurous acid it readily dissolves, and by gradual evaporation it is deposited in the form of transparent depressed tetrahedral pyramids. To the taste it is at first sweetish and earthy, and afterwards sulphurous. When exposed to the air it becomes opake, and is very slowly converted into a sulphat. It is soluble in 20 parts of water at the common temperature; boiling water takes up an additional portion, which it deposits in crystals on cooling. It is very readily converted into sulphat by exposure to the air. When exposed to a dry heat it softens and assumes the consistence of viscid gum, and at length dries, having lost 45 per cent. which is nearly pure water; at a higher heat the sulphurous acid rises unaltered, and the earth remains behind. From this mode of analysis it appears, according to Fourcroy, to consist of

39	Sulphurous acid
16	Magnesia
45	Water
100	

It is decomposed by the alkaline and earthy-alkaline carbonats; by the sulphats of alumine and zircon; by the earthy nitrats; by the phosphats of the alkalies, and of lime, glycine, alumine, and zircon; and the alkaline borats. It is not applied to any use.

AMMONIACO-MAGNESIAN SULPHITE.

This salt is formed, according to Fourcroy, by mixing magnesia with sulphite of ammonia, or ammonia with sulphite of magnesia, or by

adding together the two sulphites. It occurs in the state of small transparent indeterminate crystals; it is less soluble in water than either of the two sulphites separately, of which it is composed. By exposure to air it changes into the triple sulphat of ammonia and magnesia. When heated it gives out first sulphurous acid, then acidulous sulphite of ammonia sublimes, and pure magnesia remains behind. The proportion of its constituent parts has not been ascertained. It is decomposable by barytes, strontian, lime, and the fixed alkalies. It is not made any use of.

Sulphite of Alumine.

This salt is formed from pure alumine, according to the process already mentioned. It is in the state of a white soft powder; to the taste it is sweetish, and then sulphureous. It is insoluble in water, but is taken up by an excess of acid. It is not crystallizable. By exposure to the air it is gradually converted into sulphat. When heated, sulphurous acid is driven off and the earth remains behind, together with a little sulphat. It is composed, according to Dr. Thomson, of

32	Sulphurous acid
44	Alumine
24	Water
100	

It is not applied to any use.

SUMACH. *Rhus Coriaria*, Linn.

The sumach is a shrub which grows naturally in Spain, Portugal, Syria, and many parts of the Levant, and is largely employed in dyeing.[a] Every part of the tree appears impregnated with astringent matter: the entire twigs and branches are the parts employed, which are dried, and ground in a mill into a coarse brown or yellowish-green powder, which is the state in which it is imported.

Sumach readily yields a yellowish green infusion with warm water, which soon turns brown on exposure to air. This infusion gives a small quantity of yellow lake with alum, and with the solutions of iron it forms an abundant black or dark brown precipitate, shewing the presence of gallic acid. It is largely used in dyeing; by itself it gives a yellow-buff or fawn colour tending to green, which however is fugitive unless fixed by a mordant. If a salt of iron enters into the mordant, the black of the gallat of iron then produced mixes with the natural colour of the sumach, and a vast variety of useful grey, drab, and slate colours are brought out. Sumach, like the gall-nut, also contains a very large quantity of *Tan*, and hence will give a copious precipitate with infusion of glue or any other animal jelly; so that it has an additional use in the preparation of *leather*, the finer kinds of which (as mentioned under that article) are tanned by sumach.

A good deal of sulphat of lime is found in the infusion of sumach, by the barytic and oxalic tests. The infusion of this plant differs from that of the other astringent vegetables in giving a precipitate with the caustic alkalies, which is probably owing to the sulphat of lime which it contains. (*See the article* Tannin.) Mr. Davy obtained 165 grs. of matter soluble in water from 480 grs. of Sicilian sumach, of which he estimates 78 grs. to be tannin.

SWINESTONE. *Stinkstein*, Wern. *Pierre puante*, Broch.

Its colour is dark smoke-grey passing into greyish black, yellowish grey or blackish brown. It occurs in mass, and sometimes disseminated. Its internal lustre varies from dull to glimmering. Its fracture is fine grained splintery, or fine grained earthy; sometimes it is imperfectly lamellar or slaty; the black variety is more or less conchoidal. Its fragments are either indeterminately angular, or slaty. It sometimes contains very small-grained distinct concretions. It is opake, sometimes a little translucent on the edges. It gives a greyish-white streak, may be easily scratched with a knife; is brittle, and easily frangible; when rubbed it gives out a strong fetid urinous odour (whence its name.)

It effervesces strongly with acids, and the gas thus liberated is carbonic acid mixed with a little sulphuretted hydrogen. By calcination it becomes white, and is converted into quicklime.

It occurs in beds alternating or intermixed with stratified gypsum, or stratified limestone. It is found in England, Germany, France, and most other countries. The harder and more compact varieties being capable of a good polish are often employed in ornamental architecture for marble. It is also used as a material for building, and when burnt affords excellent quicklime. Its peculiar odour has been attributed by some to a mixture of bitumen, and hence it has been improperly confounded with bituminous limestone.

[a] Berthollet Art de la Teinture.

T

TALC. *Talk*, Wern. *Talc*, Broch.

Of this mineral there are the three following subspecies.

Subsp. Earthy Talc. Talcite of Kirwan.

Its colour is greenish-white passing into reddish white, silver-white, pale apple-green, and bright grey. It occurs disseminated, superficial, or in small kidney-shaped masses. It has a glistering pearly lustre, and is composed of slightly agglutinated scaly particles; it stains the fingers, and is very unctuous to the touch.

It is found at Sylva in Piedmont; near Freyberg in Saxony; and at Meronitz in Bohemia.

It has sometimes been confounded with agaric mineral.

2. *Subsp.* Common Talc. Venetian Talc.

Its colours are greenish white, pale apple-green, silvery-white, leek-green, and reddish or yellowish white. It occurs in mass, disseminated, and very rarely crystallized, in minute hexagonal tables confusedly grouped together. It has a considerably shining pearly lustre, passing into semi-metallic. Its fracture is curved and undulatingly lamellar; its fragments are in the form of plates or wedges. It occurs sometimes in granular distinct concretions. It is translucent and in thin plates transparent; is soft, sectile, flexible but not elastic, unctuous to the touch. It is infusible before the blowpipe without addition. According to an analysis by Hoepfer it consists of

50.	Silex
44.	Magnesia
6.	Alumine
100.	

It is rarely found except in primitive mountains particularly forming beds and veins in serpentine, accompanied by actynolite, steatite, &c. It abounds in the mountains of Tyrol and Salzburg, whence it was brought to market at Venice, and from this circumstance received the name of Venetian talc. It is also found at Zöblitz in Saxony, in Silesia, and other places.

It is employed as a basis for coloured crayons, and for the finest rouge.

3. *Subsp.* Indurated Talc.

Its colour is greenish-white of different degrees of intensity, also snow white, and yellowish white.

It occurs in mass. It has a brightly shining lustre, between pearly and greasy, passing sometimes into semi-metallic. Its fracture is curved, lamellar, passing into slaty, or coarsely radiated. Its fragments are usually in the form of blunt edged plates. It is translucent, and in thin pieces, semi-transparent; is very soft; sectile; smooth and unctuous to the touch.

Its constituent parts, according to Hoepfer, are,

38.54	Magnesia
38.12	Silex
6.66	Alumine
0.41	Lime
15.02	Iron
98.75	

It forms beds in mountains of argillaceous and micaceous schistus, of gneiss and the newest serpentine. It is accompanied by actynolite, calcareous spar, bitter spar, pyrites, and mica.

It appears to form an intermediate link between steatite and potstone. French chalk (craie de Briançon) is by some mineralogists referred to this species.

It is found in the Alps, in Stiria, Austria and Hungary, and according to Jameson in Breadalbane, and the Shetland Islands in Scotland.

TALCITE of Kirwan. See TALC *earthy*.

TAN OR TANNIN.
TANNING, *(the Art of)*

The general properties of tannin particularly as connected with the art of tanning, have been described pretty fully under the articles LEATHER and GELATIN; and the properties of the compound of tannin, gallic acid, and extract, with various earthy and other salts, which exists in the infusion of astringent vegetables, have been given under the article GALLS, to all of which we must refer the reader. It will be proper however in this place slightly to recapitulate the general properties of tannin, the methods by which chemists have endeavoured to obtain it pure, and those by which its relative proportion to the other contents of astringent infusions have been estimated. We shall also add an account of the late experiments by which Mr. Hatchett has produced a substance closely resembling tannin.

The ſubſtance called tan or tannin, is diſtinguiſhed by its ſtrong aſtringent taſte, by a peculiar ſmell, by forming immediately with a ſolution of gelatin a whitiſh compound inſoluble in water and alcohol, and by uniting to animal ſkin (which is chiefly gelatine in a condenſed ſtate) immerſed in it, rendering it harder, leſs pervious to water, and no longer ſuſceptible of putrefaction. Theſe are the peculiar advantages procured by the art of tanning which has been deſcribed under the article *Leather*.

It is not certain whether we have ever procured pure tannin, (at leaſt the natural tannin) for all the parts of vegetables that contain it alſo give out on infuſion a quantity of extract, ſometimes mucilage, often gallic acid, beſides ſome ſaline ſubſtances, and as the chemical difference between ſome of theſe bodies appears but ſlight, and as all ſoluble vegetable matter poſſeſſes many properties in common, it is extremely difficult to obtain any one of them ſeparate.

Prouſt[a] who has made many reſearches on tannin, gives the following method of obtaining it from the decoction of galls.

Pour into the decoction a ſolution of muriat of tin, which will give a copious yellow precipitate. Separate this by filtration, and when well waſhed it will conſiſt (as he aſſerts) of all the tannin united to the oxyd of tin. To ſeparate theſe two, diffuſe the precipitate in water, and paſs a current of ſulphuretted hydrogen gas through the liquid. By degrees an inſoluble hydro-ſulphuret of tin will be precipitated, and the tannin, now ſeparated from the oxyd, will reſume its ſolubility and diſſolve in the fluid, giving it the acerb taſte, and peculiar ſmell of the decoction of galls after the exceſs of ſulphuretted hydrogen has been expelled by boiling. This ſolution lathers like ſoap water on agitation, and when concentrated by boiling it depoſits a brown powder on cooling, which is re-diſſolved by heat. When evaporated to dryneſs it leaves a dry, brown, friable, reſinous looking maſs like aloes, which does not deliqueſce, has an intenſely acerb taſte, rediſſolves in water and alcohol, and then gives an immediate precipitate with the ſolutions of gelatine, which is the moſt characteriſtic property of tannin.

The clear liquor that remains in the firſt part of this proceſs (that is after adding muriat of tin to the decoction of galls) contains gallic acid and muriat of tin.

Such was the original proceſs of this ingenious chemiſt,[b] but ſubſequent experiments convinced him that it was by no means ſo accurate as he had at firſt ſuppoſed, for the oxyd of tin has ſo ſtrong an affinity for other vegetable principles and particularly for extract, that this ſubſtance when preſent (which it generally is) accompanies the tannin in its precipitation with the oxyd of tin, and alſo in its ſubſequent ſolution in water after the oxyd has been removed by ſulphuretted hydrogen. A part alſo of the compound of tannin and oxyd of tin remains in ſolution inſtead of precipitating, ſo that this method of eſtimating the proportional quantity of tannin in any ſolution would be liable to a double error.

M. Prouſt alſo tried the effect of ſimply agitating the decoction of galls with the oxyd of tin (made by nitric acid and kept under water) which in a few days abſorbed all the tannin, but it equally took away the extract, leaving the ſupernatant liquor nearly clear. He alſo found that in this way the gallic acid, and part of the tannin were deſtroyed, that is, changed in ſuch a manner, that their reſpective diſtinguiſhing properties were loſt; ſo that on the whole not much advantage can be expected in theſe experiments, from the uſe of this powerful chemical agent.

Another method[c] propoſed by the ſame chemiſt of obtaining what he conceived to be pure tannin, was to pour into an infuſion of galls, a ſolution of potaſh thoroughly ſaturated with carbonic acid, ſuch as the cryſtallized carbonat of potaſh is, which produces a yellowiſh white curdy precipitate of the ſubſtance in queſtion. The liquors ſhould not be too dilute, nor the precipitate waſhed with too much water, as it is ſoluble in water, though ſparingly. This precipitate dries but ſlowly, but when ſpread over any ſmooth ſurface, in thin layers, and ſtoved, it becomes a brittle reſinous yellow maſs. This ſubſtance diſtilled *per ſe* gives a ſaline liquor with an ammoniacal ſmell, which blackens the ſolutions of iron, and alſo a little thick butyraceous oil, and leaves a bulky coal.[d]

Mr. Davy however, on repeating theſe experiments, found that this precipitate did not exhibit the properties of pure tannin, as it wants the peculiar aſtringent taſte, is but ſlightly ſoluble in cold water and alcohol, and the ſolution is not precipitated by gelatin till it is ſaturated with an acid. It alſo gives by incineration a conſiderable quantity of carbonat of potaſh,

[a] An. Chim. tom. 25. [b] Ibid. tom. 42. [c] Ibid. tom. 35. [d] Phil. Tranſ. for 1803.

and ſome carbonat of lime.[c] It alſo affords gallic acid by diſtillation

From theſe and other facts it appears that this precipitate is not pure tannin, but is a very compounded ſubſtance containing tannin, gallic acid, alkali, and lime, and perhaps extract. The preſence of alkali is peculiarly indicated, by the circumſtance of its affording no precipitate with gelatine till ſaturated with an acid, which is preciſely the effect produced in the infuſion of galls by adding the cauſtic alkalies, as mentioned under the article *Galls*.

A compound of acid and tannin is produced on adding an acid to the infuſion of galls as has alſo been mentioned under that article. This precipitate is tenacious like pitch, and when it is waſhed with cold water, rediſſolved to ſaturation in boiling water, and a little carbonat of potaſh added to ſaturate the acid, another precipitate takes place, which now no longer contains any acid, and is ſuppoſed by Prouſt to be pure tannin. To obtain the whole of it, the remaining liquor ſhould be evaporated and then allowed to cool, and the precipitate waſhed with cold water.

This ſubſtance certainly contains the tannin more approaching to purity than in the former caſe, but as extract is alſo known to be precipitated by acids, it is probable that ſome of it is alſo contained in this caſe, and beſides it ſhews traces of gallic acid.

From all that has been done on this ſubject, it appears therefore that we cannot be certain that we have ever obtained pure tannin, free from all other admixture; and it is equally certain that none of theſe methods can extract the whole of this ſubſtance from vegetable infuſions; ſo that it is ſtill the beſt method, in experiments where the quantity of tan alone is required, to make uſe of the infuſion of animal gelatin, and eſtimate the quantity of tan from the weight of the compound of tan and gelatin thus produced.

With proper precautions, the gelatin only ſeparates the tannin from the vegetable infuſions; and this compound appears tolerably uniform in its nature, and in the proportion of its conſtituent parts, though we have not yet been able to ſeparate them without deſtroying the characteriſtic properties of each.

In applying the ſolution of gelatin to infuſions containing tannin, ſeveral circumſtances muſt be noted.[d] It appears, in the firſt place, that the mere dilution of the liquids influences the quantity of precipitate, this being the greateſt, in proportion as the ſolution of tannin is moſt concentrated.

This circumſtance introduces an unavoidable ſource of error, for though an uniform ſtandard of ſtrength may be adopted for the gelatin, by diſſolving a given quantity of iſinglaſs (which is nearly pure gelatin) in a known bulk of water, it is impoſſible to make an equally uniform ſolution of tannin from a compound vegetable ſubſtance.

The proportions of iſinglaſs and water employed by Mr Davy are 6 grains of the former to an ounce of liquid, which is nearly as ſtrong as can be made at a moderate temperature, without being inconveniently ſtiff and gelatinous. Care muſt be taken not to add an over proportion of gelatin to the vegetable infuſion, for when this happens, it appears that ſome of the compound is diſſolved in the mixture, as leſs of it is precipitated. Probably therefore gelatin unites with tannin in different proportions, and the compound is only inſoluble when the gelatin is in the inferior proportion. The precipitate ſhould always be dried at a tolerably uniform temperature ſomewhat higher than that of the atmoſphere. This precipitate is compoſed, according to Mr. Davy, on an average, of about 54 per cent. of gelatin, and 46 of tannin. There is much more tannin, however, in this compound, than in tanned leather, or ſkin ſaturated with tannin, though the conſtituent parts are nearly the ſame.

It remains to mention a very curious production of tannin by artificial means from ſubſtances which do not naturally contain a particle of it, lately diſcovered by Mr. Hatchett,[e] and partially noticed in this volume under the article *Reſin*.

The ingenious author was led to the diſcovery by purſuing his former experiments on *Bitumens* and *Bovey Coal*, and in particular on their habitudes with nitric acid. When a pure reſin is digeſted with this acid it is converted into an orange-coloured viſcid ſubſtance, which at firſt ſeparates, but by a further affuſion of acid is rendered ſoluble in water and alcohol. On the other hand when a bitumen is treated in this manner, the firſt effect of the acid is to ſeparate this orange-yellow ſubſtance, and at the ſame time to produce a *very dark brown ſolution*. Now as the bitumens were ſhewn by previous experiments to conſiſt of a reſin holding a portion of uncombined carbon, Mr. H. conceived that a ſeparation of theſe

[d] Davy. [e] Phil. Tranſ. for 1805 & 6.

two ſubſtances was effected by the acid, and that the brown ſolution contained only the uncombined carbon diſſolved in nitric acid, whilſt the orange-coloured maſs was furniſhed by the reſin. This was confirmed by treating in the ſame way amber, aſphaltum, different ſpecies of pit-coal, and laſtly pure charcoal, all of which yielded the brown ſolution in abundance, particularly the charcoal, but only thoſe ſubſtances that contained bitumen depoſited any of the orange-coloured maſs. The charcoal therefore yielded none of this latter, but diſſolved compleatly in the acid, making a dark reddiſh-brown liquid. This liquid was ſlowly evaporated to dryneſs, and left a brown gloſſy ſubſtance, with a reſinous fracture, the properties of which are the following:

1. It is ſpeedily diſſolved by cold water and by alcohol.

2. Its taſte is highly aſtringent.

3. Expoſed to heat it ſmokes but little, ſwells much, and affords a bulky coal.

4. The watery ſolution reddens litmus paper.

5. The ſame ſolution copiouſly decompoſes the metallic ſalts, eſpecially muriat of tin, acetite of lead, and red ſulphat of iron, forming brown or chocolate-coloured precipitates.

6. It precipitates gold from its ſolution, in the metallic ſtate.

7. It alſo precipitates the earthy ſalts.

8. The fixed alkalies at firſt only deepen the colour of the ſolution, but after a time render it turbid.

9. Glue or iſinglaſs diſſolved in water and added to the above ſolution forms an immediate precipitate more or leſs brown according to the degree of concentration, which is inſoluble in cold or boiling water, and appears cloſely to reſemble the precipitate formed by adding gelatin to the infuſion of galls or other vegetable aſtringents.

From theſe facts it appears that whenever carbon, either as ſimple charcoal or in natural mixture with reſins in the form of bitumen or coal, is digeſted in nitric acid, it is ſpeedily diſſolved therein, and is then converted into a ſubſtance cloſely reſembling the natural *Tannin*, from which moſt of the exceſs of acid may be ſeparated by cautious drying; and re-ſolution in water.

This artificial tannin is probably purer than tannin procured in any way from vegetable infuſions, being entirely free from gallic acid, though ſomething reſembling extract is produced along with the tannin.

Further experiments confirm the ſtrong reſemblance of the artificial with the natural tannin. When ſulphuric acid is added to the artificial ſolution it becomes turbid, and a copious brown precipitate ſubſides, which is ſoluble in boiling water, and then precipitates gelatin. When carbonat of potaſh is added, the colour is deepened, and a brown flocculent ſubſtance ſubſides.

Pure ammonia diſſolves the artificial tan, and this ſolution gives no precipitate with gelatin till neutralized by an acid. In all theſe circumſtances it agrees cloſely with the natural tannin.

When a ſolution of artificial tannin, made by pure charcoal and nitric acid, is precipitated as much as poſſible by gelatin, the ſupernatant liquor yields by ſlow evaporation to dryneſs, a light brittle cinnamon-brown ſubſtance, with a ſtrong odour reſembling that of oak-bark, ſoluble in water, ſcarcely acted on by gelatin, but precipitating the ſolutions of iron, tin, and lead, and which in ſome degree reſembles extract; ſo that this latter ſubſtance appears alſo to be an artificial as well as a natural production.

The chief, if not the only material, difference which has hitherto been found between the natural and the artificial tannin is, that the former has its diſtinguiſhing properties, particularly that of precipitating gelatin, entirely deſtroyed by digeſtion with nitric acid; whereas the artificial kind is made by means of this acid, and reſiſts all further change by it, in any temperature, at leaſt for a conſiderable length of time.

It has been mentioned that when nitric acid is digeſted with any ſpecies of reſin, if the latter contains no uncombined carbon, it is reſolved into an orange-coloured viſcid maſs, of itſelf inſoluble in the liquid, but which may be diſſolved by a further affuſion of acid. In this ſtate it gives no precipitate with gelatin, and therefore contains no tannin fully formed; but Mr. Hatchett found that on repeatedly abſtracting the acid to dryneſs, the reſidue became ſoluble in water, forming a clear yellow liquid, in which the preſence of tannin was then detected by the ſolution of iſinglaſs. Any kind of reſin will yield tannin in this manner, as will ſome of the gum reſins that have been examined. This therefore is a ſecond mode of forming the artificial tannin. The ſimple nitrous ſolution of indigo alſo gives a portion of tannin, together with an intenſely bitter cryſtallizable ſubſtance.

There is ſtill another method of producing

it, which is by means of sulphuric acid. When a resin is immersed in this acid it is speedily dissolved, forming a brown-red solution, which by continuing the digestion turns to black. Heat is not necessary to effect the solution, but hastens it. After a time much sulphureous and carbonic acids are given out, and if after this the solution is copiously diluted with cold water a black mass subsides, which is partially soluble in alcohol, and this alcoholic solution is totally decomposed by gelatin, and therefore contains an artificial tannin. It is not necessary however to make a compleat solution of the resin in this acid, for if it is long digested with a smaller quantity of the acid, the same gasses are given out, and the residue becomes converted into a black charred mass from which tannin may be extracted by alcohol. Not only the resins, but oil, wax, camphor, and many other inflammable substances will yield tannin by digestion with sulphuric acid, but some with much more ease than others. The tannin appears to be the same in all, and there appears to be a certain period of the process when the production of the tannin has arrived at its greatest quantity, after which a gradual diminution of it takes place, and it finally disappears, and the substance becomes mere coal.

There is therefore this difference between the action of the nitric and sulphuric acid upon resins and other inflammable bodies, which is, that the production of tannin by the former acid is an ultimate effect, beyond which, no further change takes place by a continuation of the process; whereas with the sulphuric, it is only an intermediate product, which is lost on further digestion.

The tannin produced by sulphuric acid appears also to be much weaker in energy than that formed by the nitric.

From all these original and truly valuable experiments therefore, it appears that artificial tannin may be made in the following ways:

1. By simply dissolving in nitric acid, either pure charcoal, vegetable or animal, or vegetable compounds that contain naturally any quantity of uncombined charcoal, or in which charcoal has been produced by previous exposure to heat, or by sulphuric acid. In these the quantity of tannin is directly proportioned to that of the charcoal solely.

2. By repeatedly abstracting nitric acid off most of the resins, and some other vegetable inflammables, which is totally independent of any uncombined charcoal that they may contain.

3. By long digestion of resins, oils, and some other substances with sulphuric acid, stopping the process before the ultimate effect of the acid is produced, and extracting the tannin from the half-charred mass by alcohol.

Further experiments are required to ascertain what difference there may be between these varieties of artificial tannin, and between these and natural tannin. With respect to the latter question, one striking difference appears, which is, that the natural species is totally decomposed by nitric acid, whereas the artificial is both produced by it, and is not easily, if at all, alterable by any continuance of its action.

TANTALIUM.

Of this metallic substance, newly discovered by Ekeberg, the following are all the particulars that have hitherto been published.

§. 1. *Ores of Tantalium.*

Sp. 1. Tantalite.

The external colour of this mineral is iron-black, that of a recent fracture is somewhat lighter with a bluish tinge; when pulverized it is a blackish grey. It occurs imbedded in detached crystals of the size of a hazel-nut; the form of the crystals is an ill defined octohedron. Its fracture is compact, and presents a faint metallic lustre. It gives sparks when struck against the steel. Sp. gr. 7.95.

Its component parts are tantalium, iron, and manganese.

It occurs near Brockaern in the parish of Rimito in the government of Åbo in Finland, in a vein of quartz and mica, traversing a rock of granite.

Sp. 2. Yttrotantalite.

The colour of this mineral when recently broken is iron black. It occurs in nodules not larger than a hazel-nut. Its fracture is compact granular with a metallic lustre. It may be scratched, though with difficulty, by a knife. The colour of its streak is greyish. Sp. gr. about 5.1.

It is composed of tantalium and yttria.

It occurs at Ytterby in Sweden, in a granite rock, accompanied by gadolinite.

§. 2. *Physical and Chemical Properties.*

Tantalium is obtained from its ores by treating them alternately with caustic fixed alkali, and muriatic or nitro-muriatic acid. The alkaline solution being supersaturated with an acid lets fall a white powder which is oxyd of tantalium, the specific gravity of which after ignition is =6.5. This oxyd if strongly heated

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in a crucible lined with charcoal is reduced into a button of moderate hardneſs with a ſlight metallic luſtre ſuperficially, but internally blackiſh and quite dull. The only action which the acids have on this regulus, is to reduce it to the ſtate of white oxyd. Borax and phoſphat of ſoda, when aſſiſted by the blowpipe, diſſolve this oxyd, but receive from it no tinge of colour.

TAR. See TURPENTINE.

TAR, *Mineral*. See BITUMEN.

TARRAS. See CEMENTS, *Calcareous*.

TARTAR. *Weinſtein*. Germ.

The ſubſtance called *Tartar*, is a hard, brittle, brown-red maſs, interſperſed with imperfectly cryſtallized particles, which is depoſited on the ſides of wine-casks, during, and after fermentation of the grape-juice, in the form of a thick ſolid cruſt. In this ſtate it is alſo called *Crude* or *Rough Tartar* or *Argol*, to diſtinguiſh it from that which is purified in the way that will be preſently mentioned.

Tartar is not furniſhed in equal quantity from all wines, but the more coloured and ſtronger-bodied wines yield the moſt. Tartar has a vinous and ſlightly acid taſte. It conſiſts of a large quantity of extractive matter, ſcarcely ſoluble in water, to which it owes its colour, and of a ſalt, quite white when pure, compoſed of acid of tartar united to a ſmall portion of potaſh, leſs than is required for the ſaturation of the acid, but which in this proportion forms a diſtinct cryſtallizable ſalt of conſiderable importance in ſeveral arts and manufactures.

This ſalt when pure is called *Purified Tartar*, *Cream of Tartar*, *Cryſtals of Tartar*, or with more preciſion, *Acidulous Tartrite of Potaſh*, or *Super-Tartrite of Potaſh*. It is alſo called ſimply *Tartar*, but it is better to confine the term Tartar to the entire unpurified maſs. Tartar is not entirely a product of fermentation, for it is contained in the *Muſt*, or grape-juice, and aſſiſts in the proceſs of fermentation and the production of alcohol. The ſame ſalt in different combinations, has alſo been found native in ſome other vegetable juices.

Crude tartar is uſed pretty largely as a flux in the aſſaying of ores. As it contains both alkali and carbonaceous matter, it acts both in aſſiſting the fuſion of refractory ores, and in reducing metallic ſalts and oxyds. When heated *per ſe* to redneſs in cloſe veſſels, the extractive matter and the tartareous acid both become charred, and a black alkaline carbonaceous maſs is the reſult. In open veſſels the charcoal burns off totally, and at laſt nothing but pure white carbonat of potaſh remains.

But the greater part of the tartar is refined to extract the pure ſalt, which is performed largely in the South of France, near Montpellier, and alſo at Venice, and in two different methods.

The Venetian is the following:[a] The crude tartar is firſt dried in an iron boiler, with a very gentle heat and frequent ſtirring, that the acid may not be burnt, and is then pounded in iron mortars. The ground tartar is then diſtributed into wooden tubs, and boiling water poured upon it, which diſſolves the ſalt, and leaves a ſediment which is thrown away. The clear ſolution is left three days at reſt, during which time it depoſits browniſh cryſtals of tartar. The mother liquor from this operation is reſerved, and is uſed hot in the ſubſequent proceſs in the firſt lixiviation of the tartar. The browniſh cryſtals of tartar are then put into a copper boiler, with the mother-liquor of former proceſſes, and ſlowly brought to boil, by which a ſaturated ſolution of a deep yellow wine colour is produced. This is clarified in the following way: a workman ſtands by the ſide of the copper with a baſket of eggs, and a bucket full of finely ſifted wood aſhes. He begins with breaking one of the eggs, and putting the white of it only into a bowl; he beats this up with ſome of the boiling liquor, and then pours the whole into the boiler: he then inſtantly throws in a ladle-full of the wood-aſhes, and ſtirs up the liquor from the bottom. A briſk effervеſcence takes place, and the ſurface is covered with a red ſcum, which is carefully taken off with a perforated ſkimming-diſh and put aſide: a ſecond portion of aſhes is then added, and the effervеſcence and ſcum are renewed and treated as before. The whole of this operation is repeated fourteen or fifteen times, after which the liquor becomes quite clear and colourleſs. The fire is then withdrawn, and the liquor ſuffered to remain perfectly at reſt for three days. On the fourth, a dirty white ſaline cruſt is removed from the ſurface, and two-thirds of the liquor laded out: the cryſtals on the ſides are then collected by a ladle and waſhed in the remaining liquor; they are thus obtained perfectly clean, and require no further preparation than drying on a wicker frame. The cryſtals from the bottom are ſtill ſomewhat coloured, and are either ſold as an inferior ſort, or are refined again with freſh portions of the crude tartar. The liquor that remains in the boiler after the depoſition of the cryſtals is a cold ſaturated ſolution

[a] Deſmaret, in Journ. Phyſ. tom. 1, p. 67.

of tartar, and is employed in the first lixiviation of the rough tartar.

Tartar is refined near Montpellier in the following manner, according to the description given by M. Fizes,[b] which has been found so convenient and efficacious that little if any change has been made in it for a century.[c]

The apparatus required for this purpose is 1st, a large copper boiler; 2d, a stone cistern, larger than the boiler; 3d, a number of glazed earthen pots (generally 27) which, together, hold somewhat more than the boiler; 4th, some strainers of coarse cloth stretched on wooden frames; 5th, four smaller copper boilers which, together, hold as much as the larger boiler, and are used in the refining part of the process; and 6th, a mill to grind the tartar.

The large copper is first filled with two-thirds of mother liquor, remaining from the previous operations, and one-third of spring water, a quantity of rough tartar is then thrown in, and when the liquor is saturated and boiling it is strained into the earthen pots. In about half an hour the liquor in these pots though still very hot, begins to deposit crystals on the surface and sides of the pot, during which time more liquor and tartar are thrown into the large copper as at first.

The liquor in the pots is then emptied into the stone cistern, leaving the crystallized crust of tartar behind; and when the second boiling is saturated, the pots are again filled as before, and the large copper again charged with the clear liquor from the cistern, and fresh tartar. By thus five times alternately preparing a hot saturated solution, and allowing it partially to deposit its tartar in the pots, the latter become lined to a considerable thickness with a crust of reddish-white tartar, much purer than at first, and which obviously consists of an irregular crystallized saline mass, and when washed with cold water is fit for the second, or proper refining process. For this purpose the four small boilers are filled with water, in which a small quantity of clay is diffused, which renders it milky, rejecting the stony and larger particles of earth. The half-purified tartar is then added in such proportion that the water when boiling shall be sufficient to dissolve all the soluble part, and the ebullition is continued for a quarter of an hour; the fire is then withdrawn, and the liquor allowed to remain at rest till the next day. It is then found covered on the surface with a white hard saline crust, and a similar crust, but more distinctly crystallized, has concreted on the sides and bottom of the boiler. They are both very pure tartar, the crust on the surface, which is an amorphous mass, is called *Cream of tartar*, and the other, *Crystals of tartar*, but they are indiscriminately mixed.

The crust is then broken down and falls to the bottom, and the liquor, which is a clear pale red, is poured off gently into the stone cistern, till it begins to run white owing to the clay at bottom, which latter portion passes into a separate vessel. The whole mass of solid tartar left in the boiler is then washed with cold water, till all the foulness (which is merely superficial) is got out, and the water comes away quite clear, after which the purified tartar is taken out and dried on stoves or in the sun, and is perfectly pure and white. The ordinary rough tartar yields about three-fifths of its weight of the white pure salt. All the residuary liquors are employed in subsequent operations in the way already mentioned.

The above two processes of purifying tartar are considerably simple. Tartar consists of the pure super-tartrite of potash, or cream of tartar, united with a large quantity of extractive and colouring matter. Of these, the pure salt is entirely soluble in water, and much more so in hot than cold water, but it requires a very large proportion of water for solution; for even at a boiling temperature one ounce of the saturated solution holds no more than 16 grs. or $\frac{1}{30}$ of its weight of the salt, and on cooling only three or four grains are retained in solution. Hence the necessity of using a very large bulk of fluid in the processes of solution and crystallization, and the advantage of employing the mother liquors or cold saturated solutions of former processes. In each of these methods the tartar is first considerably purified by simple solution, filtration, and crystallization, but the subsequent part of the process differs materially. In the Venetian method the white of egg is doubtless a very excellent, though somewhat more expensive, substance for clarification; but the use of the wood-ash is not very obvious, and would seem to be so far injurious as its alkali must neutralize a portion of the tartareous acid, and diminish the quantity of purified tartar by converting a portion of it to tartrite of potash, or that combination of this acid and potash in which the acid and alkali are in mutual saturation, and which being very soluble would remain in solution. Whether, as has been stated by some, the alkali of the ashes would render the whole mass of purified tartar less acidulous

[b] Mem. de l'Acad. for 1725. [c] Chaptal.

may be somewhat doubted, for the super-tartrite of potash appears in all experiments to be a pretty uniform salt; and its little solubility, and the readiness with which it separates from its hot saturated solution, contribute to preserve its composition unvaried in any mixture where it is produced at all.

In the Montpellier mode of purification the earth used appears to be a tolerably pure clay, which readily diffuses itself in water, and probably any other white clay would answer as well. The effect of the clay is to absorb to itself the mucilaginous and coloured extract, and to carry it down in the form of an insoluble sediment; and when this operation is properly performed it appears on the whole to be superior to the Venetian mode. The clay however should be free from any admixture of chalk, and should not effervesce with acids, for the chalk would readily neutralize that excess of acid which is essential to the composition of cream of tartar, as is seen in the process where it is intentionally added to procure the tartareous acid, and will be described under that article.

Cream of tartar is a very valuable salt. It is chiefly used in dyeing, especially in giving the scarlet and other modifications of the cochineal colours as described under the article *Dyeing*. It is also frequently combined with alum, as a mordant in fixing colours. An agreeable and very cheap acidulous drink is made by dissolving this salt in water. The other chemical properties of this salt will be mentioned under the articles TARTRITES and TARTAREOUS ACID.

TARTAR EMETIC. See ANTIMONY.

TARTAR *Regenerated*. See ACETITE *of Potash*.

TARTAR. *Salt of*. A very pure *Carbonat of Potash* is made by calcining cream of tartar either *per se* or with nitre, whence the term Salt of tartar has long been, and still is, very commonly applied to the purest sub-carbonat of potash in whatever way obtained, and some of the salts with this alkali have had the name of tartar, as the following:

TARTAR *Vitriolated*. See SULPHAT *of Potash*.

TARTAR *Soluble*. See TARTRITE *of Potash*.

TARTAREOUS ACID.

It was Scheele, whose admirable ingenuity first devised the method of separating from cream of tartar the pure tartareous acid, and obtaining it in a solid crystallized form.

His process, with slight variation, is the following, which very closely resembles the method used by this chemist to obtain the *Citric* acid: dissolve any given quantity of cream of tartar in boiling water, and whilst boiling add gradually some clean powdered chalk. A copious effervescence will arise, and the addition of chalk must be continued till this ceases, when the mixture may be set by to cool. It then contains a white dense sediment, which consists of the lime of the chalk, united with the excess only of the acid of the cream of tartar; and the supernatant liquor is therefore a solution of the cream of tartar deprived of its excess of acid, or neutral *tartrite of potash*, or *soluble tartar* as it is also called, and which may be obtained crystallized by subsequent evaporation. Wash the precipitated tartrite of lime repeatedly with cold water, then put it into a glass vessel, and add to it a diluted sulphuric acid, composed of as much concentrated acid as is equal to the weight of chalk employed in saturating the cream of tartar, mixed with four or five times its weight of water.

The sulphuric acid having a stronger affinity for the lime than the tartareous acid has, totally decomposes the tartrite of lime during a digestion of two or three days (or in a shorter time if assisted by a gentle heat) and the white sediment, though it does not alter its appearance, is changed to sulphat of lime, whilst the supernatant liquor contains naked acid of tartar. Then pour off the clear liquor, wash the sulphat of lime to extract all the adhering acid, and add the washings to the former liquor, and evaporate the whole (at first with a boiling heat, and as it concentrates, with a much gentler warmth) till it is of a thick syrupy consistence, and then set it by for some hours that all the selenite which it may hold in solution may be deposited. Then again dilute the mixture with cold water sufficient to redissolve every thing but the selenite, and slowly evaporate the solution to a syrupy consistence, and after some hours it will deposit the pure tartareous acid in crystals, which are generally pretty large irregular hexahedrons. Cream of tartar decomposed in this way by chalk (and therefore only partially) will yield about a third of its weight of the crystallized acid. This quantity however must not be taken as the proportion of the acid in cream of tartar, for much of the weight of the crystallized acid is water of crystallization, whereas the cream of tartar contains very little water.

Some nicety of management is required to obtain the utmost quantity of the acid and with

the least repetition of the alternate solutions and evaporations. M. Lowitz[d] finds that it is better to use a slight excess of sulphuric acid in the decomposition of the tartrite of lime to ensure the total separation of the tartareous acid; for if too little sulphuric acid were added, the mixture would consist of tartareous acid, of sulphat of lime, and of some undecomposed tartrite of lime, which latter is readily soluble in an excess of its own acid, so that the clear liquor would not be pure tartareous acid, but a very acid solution of tartrite of lime, from which the pure acid would crystallize with difficulty. On the other hand, if there was any considerable excess of sulphuric acid it would produce equal inconvenience, both by dissolving some of the sulphat of lime, and also, when the acid liquor was much concentrated, by partially decomposing and colouring the tartareous acid and lessening the product.

To ascertain whether the sulphuric acid has been added in due proportion, take out a little of the clear liquor remaining after the tartrite of lime has been duly digested with the sulphuric acid, and having diluted it, drop in some solution of acetited lead as long as any precipitate falls down, which wi l therefore consist either entirely of tartrite of lead, or of a mixture of this salt with sulphat of lead, according as there is or is not any excess of sulphuric acid in the liquor. Then add some pure and moderately strong nitric acid, and, if the precipitate consists merely of tartrite of lead, it will be redissolved totally and immediately, and the solution will remain clear for some hours. If the precipitate contains much sulphat of lead mixed with the tartrite it will not be wholly redissolved: but if only a small quantity of sulphat of lead be mixed with the tartrite it will first be totally redissolved, and in a few minutes after will become somewhat turbid. This latter is the exact point to be desired, as it indicates a slight excess of sulphuric acid, and the liquor may be brought to this state by adding either more sulphuric acid, or some reserved tartrite of lime, according to circumstances.

In the above mentioned mode of obtaining tartareous acid, chalk, or carbonat of lime, is used to decompose the cream of tartar, which it does merely by engaging the excess of acid and leaving the remainder of the salt in the state of tartrite of potash. But if quick-lime be substituted to the chalk, the whole of the cream of tartar is decomposed, a much larger quantity of tartrite of lime, and consequently of tartareous acid, is obtained, and the supernatant liquor is a solution of caustic potash. It has been found however by Vauquelin, that the potash retains a small quantity of tartrite of lime in solution, so that when the alkaline liquor is evaporated nearly to dryness it gelatinizes by cooling, owing to the separation of this calcareous salt. It may be decomposed by carbonat of potash or soda, which produces carbonat of lime and tartrite of the alkali employed: or the tartareous acid may be destroyed by calcination, and the lime, carbonated in the process, will remain.

In using lime to decompose cream of tartar, the quantity to be added is not so readily ascertained as with chalk, where the cessation of the effervescence is the sign of the saturation of the acid. Where the lime is well burnt and of uniform purity, a little experience will guide the operator with sufficient certainty. Calculating from the observed proportions of acid in the tartar, and of chalk required in the first-mentioned process, and of pure lime in chalk, we may estimate that all the acid in 100 parts of cream of tartar (which Thenard[e] reckons at 57 per cent.) will require full 42 parts of pure lime for its saturation, and somewhat more lime should perhaps be added to ensure the complete decomposition of the tartar. The lime should be previously slacked and mixed with sufficient water to bring it to the consistence of paste.

Lowitz has proposed another method which is perhaps preferable in every respect, except that it is somewhat more expensive, and that no caustic alkali is obtained. It consists first in decomposing the cream of tartar by chalk in the usual way, added as long as any effervescence takes place; and then pouring into the filtered supernatant liquor muriat of lime as long as any precipitate falls down. By this means the tartrite of potash in the liquor is totally decomposed, muriat of potash remains in solution, and the precipitated tartrite of lime is added to that produced by the chalk; and both are afterwards decomposed by sulphuric acid in the usual way. The same chemist also advises to add to the solution of tartareous acid in the last part of the process a quantity of *Charcoal* powder, the depurating power of which has been mentioned under that article. This, however, is certainly not essential to the obtaining a perfectly fine colourless crystallized acid, and, we believe, is seldom if ever used.

Tartareous acid has a strong and simply acid taste, and is soluble in five or six parts of cold

[d] An. Chim. Tom. 34.

[e] An. Chim. Tom. 41. p. 51.

water, and in much leſs when boiling. The cryſtals are permanent in the air.

When heated *per ſe* in a retort with a receiver this acid melts, boils up, and exhales a ſour pungent vapour, which condenſes in the receiver into a red acid empyreumatic liquor, equal to about a quarter of the weight of the tartareous acid.

This liquor has a pungent acid and empyreumatic taſte, ſtrongly reddens litmus, and effervesces with the alkaline carbonats. It is called the Pyrotartareous acid, which has not been much examined. The other products from the diſtillation of tartareous acid, are a large quantity of carburetted hydrogen and carbonic acid gas, and a ſoft ſpongy coal is left in the retort, which, heated in the open air, burns with ſcarcely any reſidue.

The tartareous acid, beſides being found native in ſome vegetable juices, and in the depoſit from wine during and after fermentation, is alſo produced by the action of nitric acid on alcohol. A further digeſtion of tartareous with nitric acid converts the former into oxalic acid, and a ſtill further digeſtion changes the whole of the vegetable acid into vinegar. Theſe curious experiments which were at firſt noticed by Scheele, have been more fully examined by Hermbſtaedt and other chemiſts, and are detailed under the article *Acetous* acid (p. 4.)

The compounds of the tartareous acid with the alkaline and earthy baſes, will be mentioned in the following article.

This acid is compoſed, according to Fourcroy[f] and Vauquelin, of 70.5 of oxygen, 19 of carbon, and 10.5 of hydrogen, and differs from the oxalic acid in containing more carbon and leſs oxygen. The order of affinity of this acid for the ſeveral baſes is (according to Thenard) lime, barytes, ſtrontian, potaſh, ſoda, ammonia, magneſia, and alumine.

TARTRITES.

The diſtinct combinations of the tartareous acid with the ſeveral baſes, are particularly numerous, as with ſome it forms two ſalts, differing in the proportions of acid and baſe, and as it is peculiarly liable to form triple ſalts in which two baſes are united with their reſpective portion of acid into one uniform compound.

All the ſoluble alkaline and earthy tartrites are decompoſed by the ſalts of lead, and the acid of all is deſtroyed by calcination, leaving the baſe in the ſtate of carbonat.

Super-tartrite of Potash. *Cream of Tartar. Tartareous Acidulum.*

The origin and manufacture of this ſalt has been mentioned under the article *Tartar*. It is compoſed of potaſh and tartareous acid in exceſs, and hence has an acid taſte and reddens blue vegetable colours. It is ſoluble with great difficulty, requiring about 30 parts of boiling water, and full 120 parts of cold water, and hence a hot ſaturated ſolution begins to depoſit cryſtals almoſt immediately after it begins to cool.

The affinity between the tartareous acid and that proportion of potaſh which conſtitutes the ſuper-tartrite, is ſo great that the acid of tartar will decompoſe, partially or totally, all the neutral ſalts of potaſh, even the ſulphat. But on the other hand, the affinity between the ſuper-tartrite and that additional quantity of potaſh which is neceſſary for complete ſaturation of this acid, (or which conſtitutes the tartrite of potaſh,) is much weaker than that of moſt other acids for potaſh, and hence ariſes a great number of decompoſitions when tartareous acid, potaſh, and any other acid are mixed in different ways. Thus if a ſolution of tartareous acid is poured into a ſolution of ſulphat of potaſh, rather concentrated, in a few ſeconds the mixture becomes turbid, and ſoon a quantity of a white granular powder falls to the bottom, which is cream of tartar, and may be diſtinguiſhed as ſuch (when rinced with cold water) by feeling hard and granular in the mouth, with a ſlightly acidulous taſte, being much more ſoluble in boiling than in cold water, and when heated by the blow-pipe, blackening, ſwelling up, and finally being reduced to a globule of pure carbonat of potaſh. The ſupernatant liquor conſiſts of the remainder of the potaſh of the ſalt, united with the whole of the ſulphuric acid, and no further addition of tartareous acid will complete the decompoſition. Two acidulous ſalts therefore are produced in this caſe, the ſuper-tartrite and the ſuper-ſulphat of potaſh, of which the former is moſtly precipitated, and the latter remains in ſolution. On the other hand, a production of cream of tartar takes place when dilute ſulphuric or any other acid is added to tartrite of potaſh. The acid added takes away from the tartrite only that quantity of potaſh which makes the difference between the tartrite and the ſuper-tartrite, and the latter is precipitated, and is not further acted on by any exceſs of the ſulphuric acid. This property of the tartareous acid, of decompoſing the neutral ſalts with the baſis of potaſh, is very uſeful in analyſis, as it diſtinguiſhes

[f] Syſteme, &c.

them at once from the correſponding ſalts of ſoda and ammonia, which are not decompoſed in the ſame way.

By ſaturating the exceſs of acid in cream of tartar with the ſeveral baſes (potaſh excepted) various compound or triple ſalts are produced, which will be mentioned preſently.

To obviate the inconvenience ſometimes produced by the very ſparing ſolubility of cream of tartar, Lemery has recommended the addition of borax. But as this latter ſalt contains an exceſs of alkali, it is obvious that the acid of the tartar would be neutralized, and a very different ſalt would be produced, namely, the tartrite of potaſh and ſoda, or Rochelle ſalt, which will be preſently deſcribed, and which of itſelf is highly ſoluble without the aſſiſtance of borax. It appears however that ſimple boracic acid[g] has the power of rendering four times its weight of cream of tartar ſoluble in as little as five or ſix parts of hot water, and probably without effecting any decompoſition of the tartar, ſince the boracic acid is known to be remarkably weak in its affinity for the ſeveral baſes.

If a ſolution of cream of tartar in water is expoſed to the air for a length of time, it gradually becomes turbid, a number of mucous flocculi are depoſited, and in the courſe of ſome months it ceaſes to be acidulous, after which it becomes ſenſibly alkaline to the taſte and to chemical teſts, and it is finally converted into a weak ſolution of carbonat of potaſh, the tartareous acid totally diſappearing, and carbonic acid taking its place. Fire operates a more rapid deſtruction of the tartareous acid, for if cream of tartar is calcined in an open fire with a red heat, it firſt ſoftens, blackens, becomes of a paſty conſiſtence, the acid burns off with flame and ſmoke, and finally a white carbonat of potaſh is left. The alkali procured in this way is very pure, and is often obtained for the laboratory by moiſtening crude tartar or cream of tartar to the conſiſtence of ſtiff paſte, wrapping up ſmall parcels of it in brown paper, and arranging them in a grate or furnace of any kind with charcoal, and kindling it. After the charcoal has burnt out, the tartar is converted into lumps of carbonat of potaſh, which ſtill cohere, and may be readily picked out of the aſhes of the charcoal. A very pure carbonat of potaſh may alſo be made by deflagrating in a red-hot crucible equal parts of nitre and cream of tartar.

This ſalt is compoſed, according to Thenard,[h] of 57 per cent. of tartareous acid, and 33 of potaſh, the remaining 10 parts being chiefly water of cryſtallization. Of theſe 57 parts of acid, 20 are in exceſs, ſo that the compoſition of the ſalt may be ſtated, in a different manner, to be 70 per cent. of tartrite of potaſh, and 20 of tartareous acid. The mode of analyſis will be mentioned in the next ſection.

Cream of tartar is decompoſed by lime and barytes, and probably by ſtrontian, and cauſtic potaſh is left in the ſolution.

TARTRITE OF POTASH, or *Soluble Tartar*. This ſalt, which is compoſed of tartareous acid and potaſh in mutual ſaturation, is prepared the moſt conveniently by adding cream of tartar to a hot ſolution of carbonat of potaſh. A briſk efferveſcence takes place, and the addition of the cream of tartar ſhould be continued till this ceaſes, after which the ſolution ſhould be boiled down till a pellicle appears on the ſurface, and then left to cryſtallize by cooling. The tartrite of potaſh then ſeparates generally in the form of parallelipepids, with dihedral ſummits. When this ſalt is prepared in the large way for medicinal purpoſes the evaporation is continued nearly to dryneſs, with frequent ſtirring, by which the ſalt is obtained in a ſhapeleſs granular maſs.

Tartrite of potaſh has a bitteriſh ſaline taſte, is ſomewhat deliqueſcent, and is ſoluble in about four parts of cold water, ſo that in ſolubility it remarkably exceeds cream of tartar.

It is partially decompoſed by the ſtronger acids, which abſtract a portion of its alkali, whilſt the whole of the tartareous acid remains in union with the remaining alkali in the form of cream of tartar, as already mentioned in the preceding ſection. Tartareous acid dropped into a moderately ſtrong ſolution of tartrite of potaſh alſo cauſes an immediate depoſit of cream of tartar.

Tartrite of potaſh contains, according to Thenard,[i] 48 per cent. of tartareous acid, and 43 of potaſh, the reſt being chiefly water of cryſtallization. This he eſtimates, 1ſt, by heating the ſalt to perfect dryneſs, avoiding its decompoſition; 2d, by diſſolving the remainder in water, and decompoſing it by acetited lead, and collecting the tartrite of lead thus produced, (which laſt by previous experiments, he finds to conſiſt of 34 per cent. of tartareous acid, and 66 of oxyd of lead); and, 3d, by evaporating the remaining ſolution of acetite of potaſh to dryneſs, calcining it, diſſolving the

[g] Laſſone. [h] An. Chim. tom 41. [i] Ibid.

residual carbonat of potash in nitric acid, and converting it to nitrat of potash, which last he estimates to contain 53 per cent. of potash. By the 1st process therefore the water of crystallization is ascertained; by the 2d, the tartareous acid; and by the 3d, the potash.

Tartrite of Potash and Soda. Salt of Seignette. Rochelle Salt.

This is a triple crystallizable salt first discovered by a person of the name of Seignette, at La Rochelle, and introduced by him into medicine.[1] It is prepared in the following way: boil some water, throw into it about a fifth of its weight of cream of tartar, and then add by degrees a quantity of carbonat of soda, as long as any effervescence is excited. In proportion as the excess of acid in the cream of tartar becomes saturated with the soda, the salt gradually disappears, and is finally held in perfect solution in the liquid. Evaporate the whole to the consistence of syrup, and by cooling it will yield the triple tartrite or Rochelle salt, in large transparent beautiful crystals, generally of the form of eight-sided prisms. These are often found divided longitudinally through the axis.

This salt is perfectly neutral, dissolves in about five parts of water, has a bitterish saline taste, and somewhat effloresces by exposure to the air. It is totally decomposed by barytes and lime, and the supernatant liquor then contains a mixture of potash and soda. It is composed, according to Vauquelin, of about 54 per cent. of tartrite of potash and 46 of tartrite of soda.

It is decomposed, like the simple tartrite of potash, by the stronger acids, and cream of tartar is produced.

Tartrite of Potash and Ammonia.

This triple salt is prepared in the same general manner as the preceding, by saturating the cream of tartar with carbonat of ammonia; and by evaporation and cooling the triple salt is separated. When exposed to the air it effloresces, and after a time loses its ammonia, and returns to the state of simple cream of tartar.

Tartrite of Potash and Lime, Barytes, &c.

Though lime will compleatly decompose any alkaline tartrite, as is shewn in the preparation of the tartareous acid, there appears to exist a certain affinity between tartrite of potash and lime, which tends to the formation of a triple salt. Thus though simple tartrite of lime is insoluble in cold water, no precipitate is produced by the affusion of a small quantity of lime-water into a cold solution of tartrite of potash, which must therefore be owing to the tartrite of lime, then formed, being rendered soluble by the remaining tartrite or rather subtartrite of potash.[3] Even when cream of tartar is as completely as possible decomposed by lime in substance, in the process of obtaining the acid the caustic alkaline liquor, supernatant over the precipitated tartrite of lime, still holds a small quantity of the latter in solution, as has been remarked by Vauquelin, which may be considered as a triple salt of tartareous acid, lime, and potash, the latter being in very large excess.

The same applies to barytes and strontian, the solutions of which do not immediately give a precipitate with tartrite of potash; and even if tartrite of barytes or of strontian recently formed and still wet be put into a solution of tartrite of potash, it is soon dissolved; though the mere quantity of liquid present would be entirely unable to effect a solution. There is therefore such a strong affinity between tartrite of potash and these earthy tartrites as may perhaps entitle us to consider these compound solutions as triple salts, though they have not been obtained in a crystallized form like the triple tartrite of potash and soda.

Alumine unites with still greater ease with tartrite of potash: for when this earth, recently precipitated from alum by a caustic or carbonated alkali, and still wet, is transferred to a solution of tartrite of potash, it readily dissolves therein, and forms an uncrystallizable compound which is not rendered turbid by any addition of potash or its carbonat. This last circumstance might lead to the supposition that alumine has a stronger affinity for tartareous acid than potash has, but it is contradicted by the fact, that in this case there is not the least excess of potash in the liquid; so that the alumine does not displace the alkali from the tartareous acid, but unites with them both into a triple compound. The Rochelle salt has the same habitude with alumine as the simple tartrite of potash, which therefore forms a quadruple compound of tartareous acid, potash, soda, and alumine.

Tartrite of Soda. When the tartareous acid is saturated with soda, a salt is produced, which by due evaporation may be obtained in small needled crystals, and is the tartrite of soda. This salt (with which the Rochelle salt was formerly confounded) is not very soluble in

[3] Thenard.

water. When tartrite of potash is added to this salt, each in saturated solution, large crystals of the triple tartrite, or Rochelle salt are immediately deposited.

A Super-Tartrite of Soda is formed by partially saturating tartareous acid with soda; and also by adding a strong acid to the saturated tartrite, which, analogous with the cream of tartar, is less soluble than the saturated compound, and therefore precipitates. Tartareous acid however will not form an acidulous tartrite (at least not visibly) when added to the sulphat and other salts of soda, as it will with the salts of potash.

TARTRITE OF AMMONIA.

This salt is formed by saturating the tartareous acid with ammonia or its carbonat. It crystallizes readily, and is decomposed by the fixed alkalies and alkaline earths.

A *Super-Tartrite of Ammonia* is formed in a similar manner to the super-tartrite of soda, and with the same exception of the acid not visibly decomposing the other ammoniacal salts.

EARTHY TARTRITES.

When tartareous acid is added to any soluble salt of lime, or lime to a soluble tartareous salt, a white precipitate is produced which is the *Tartrite of Lime*. This earthy salt is insoluble in mere water at a common temperature, but it dissolves readily in an excess of its own, or of any other acid that does not decompose it; such as the acetous or muriatic. It also is rendered soluble in water by the addition of potash as already mentioned under the head of Tartrite of potash. When heated strongly in an open fire the whole of the acid is consumed, and carbonat of lime remains.

Tartrite of Barytes and Strontian are formed in the same manner as tartrite of lime. They are not however so insoluble in water as this salt, and the tartrite of strontian will even crystallize from its hot-saturated solution by cooling.

With *Magnesia* and *Alumine* this acid forms very soluble compounds, which do not crystallize by evaporation, but dry up into a gummy mass.

Of all the tartrites, the cream of tartar is the only one employed in the arts, which, with the tartrite of potash and Rochelle salt, is also used in medicine.

TELESIA. See CORUNDUM.

TELLURIUM.

Tellurium is a brittle metal, nearly as fusible as lead, and easily volatilizable; it burns rapidly before the blowpipe with a greenish-blue flame, and is not much more than six times as heavy as water.

§ 1. *Ores of Tellurium.*

Tellurium has hitherto been found only in the native metallic state, and therefore, properly speaking, there is but one species; as, however, it occurs in combination, or at least mixed, with gold and other metals in various proportions, this species may conveniently be divided into the four following sub-species.

Sp. 1. Native Tellurium.

1 *Subsp.* White native Tellurium.—*Gediegen Sylvan*, Wern. *Tellure natif aurifère et ferrifère*, Hauy. *Sylvane natif*, Broch. *Sylvanite*, Kirw. *Aurum paradoxum*, or *problematicum* of the older writers.

Its colour is tin-white, passing into silver-white: it occurs massive and disseminated: it possesses a strong metallic lustre: its fracture is foliated: it presents small granular distinct concretions: it is soft and slightly ductile. Sp. gr. 5.7 to 6.1.

Before the blowpipe it melts, inflames, and is for the most part volatilized in the form of a dense white vapour, its component parts, according to Klaproth, are

92.55	Tellurium
7.2	Iron
0.25	Gold
100..	

The proportion of gold in this substance is liable to considerable variation; one specimen, examined by Klaproth, afforded him no less than 9 per cent.

It has hitherto been found only at Fatzebay, in Transylvania, where it has long been worked as a gold ore; it is at present however very scarce. It forms veins in transition mountains, particularly gräuwakke and transition limestone, and is accompanied by quartz, lithomarga, iron, pyrites, blende, and galena.

It was for a long time mistaken for auriferous antimony, to which it bears a great resemblance.

2 *Subsp.* Grey native Tellurium.—*Schrifterz*, Wern. *Sylvane graphique*, Broch. *Tellure natif graphique*, Hauy. *Aurum graphicum*, of the older writers.

Its colour is light steel-grey. It occurs massive, and crystallized in flattened tetrahedral or hexahedral prisms, either with or without te-

trahedral summits. The crystals are small and arranged in rows, generally on the surface of some other mineral: it not unfrequently happens, that to the extremities of the prisms are attached others, at right angles, giving the whole row the appearance of a line of Turkish letters or Persepolitan characters; from which circumstance is derived the trivial name of this mineral. Externally it is smooth, and shining with a metallic lustre. Its fracture is fine-grained, uneven: its fragments are indeterminately angular, sharp-edged. It is soft, brittle, and easily frangible. Sp. gr. 5.72. It is composed, according to Klaproth, of

60	Tellurium
30	Gold
10	Silver
100.	

It occurs at Offenbanya, in Transylvania, in veins in a mountain composed of sienitic porphyry and granular lime-stone, and is accompanied by quartz, iron pyrites, fahlerz, and blende.

3 *Subsp.* Yellow native Tellurium.—*Weiss Silvanerz*, Wern. *Silvane blanc*, Broch. *Tellure natif aurifère et plombifère*, Hauy. *Gelberz*, Karsten.

Its colour is silver-white, inclining strongly to brass-yellow, and sometimes to grey. It occurs disseminated, and in minute, imbedded, acicular tetrahedral prisms. Externally it has a bright metallic lustre, internally it is but feebly-shining. Its longitudinal fracture is foliated, its cross fracture is small-grained, uneven. It is soft, and moderately brittle. Sp. gr. 10.67. It is composed, according to Klaproth, of

44.75	Tellurium
26.75	Gold
19.5	Lead
8.5	Silver
0.5	Sulphur
100.	

It is found at Nagyag, in Transylvania, in quartz and brown spar, accompanied by the following subspecies, and by blende, fahlerz, and copper pyrites.

4 *Subsp.* Black native Tellurium. *Nagyagerz*, Wern. *Silvane lamelleux*, Broch. *Tellure natif aurifère et plombifère*, Hauy. *Blattererz*, Karsten.

Its colour is between iron-black and deep lead grey. It occurs in mass, disseminated, or crystallized in thin longish hexagonal tables, cellularly accumulated. Externally it is brightly shining; internally, less so, with a metallic lustre. Its fracture is curved foliated; the massive variety presents coarse-grained distinct concretions. It soils the fingers a little; is soft, sectile, flexible in thin laminæ. Sp. gr. 8.9. It is composed, according to Klaproth, of

54.	Lead
32.2	Tellurium
9.	Gold
0.5	Silver
1.3	Copper
3.	Sulphur
100.	

It occurs at Nagyag, in Transylvania, in a matrix of quartz and red manganese, accompanied by galena, iron pyrites, blende, antimony, fahlerz, and realgar.

§ 2. *Analysis of Ores.*

The best analyses that we possess of the ores of Tellurium, are by Klaproth;* to whom indeed the discovery of this metal is principally owing. In order to decompose the first subspecies, this excellent chemist pursued the following method.

(a) The ore, separated as much as possible from its stony matrix, and finely pulverized, was digested in six parts of warm muriatic acid, to which were added, cautiously and at intervals, three parts of nitric acid. The compound acid acted violently on the ore, and took up the whole of it except the quartzoze matrix.

(b) The acid solution being diluted with as much water as it would bear without decomposition, was combined with caustic fixed alkali, upon which a copious precipitate fell down; more alkali was then added, till the whole of the precipitate that was resoluble in this menstruum was taken up. There remained behind a dark-brown slimy residue, consisting of the oxyds of gold and iron.

(c) The residue of *b* was then dissolved in nitro-muriatic acid, to which was afterwards added, drop by drop, nitrat of mercury, prepared in the cold, as long as the precipitate thus formed appeared of a brown colour. This precipitate, consisting of gold and muriat of mercury, was then pretty strongly ignited in a

* Analyt. Ess. vol. ii. p. 1.

crucible with borax, by which the mercury was driven off, and a button of pure *gold* remained.

(d) To the nitro-muriatic solution *c*, was now added caustic alkali, by which the oxyd of *iron* was thrown down.

(e) The alkaline solution *b* was accurately saturated with muriatic acid, and then heated, by which a white heavy powder was obtained; which, after being washed in a mixture of equal parts of alcohol and water, and then gently dried, was pure oxyd of *Tellurium*.

The second subspecies was treated in the following manner.

(a) The finely pulverized ore was digested in nitro-muriatic acid till nothing more was taken up.

(b) The insoluble residue, consisting of quartz and muriat of silver, was fused with five times its weight of carbonated soda, by which the *silver* was obtained in the metallic state.

(c) The nitro-muriatic solution being concentrated by evaporation, was largely diluted by alcohol, upon which the oxyd of *Tellurium* precipitated; and this being re-dissolved in muriatic acid, was obtained in black metallic flocculi, by means of a bar of polished iron.

(d) The nitro-muriatic solution *c*, after separation of the tellurium, contained only *gold*, which was procured by the addition of a solution of green sulphat of iron.

The analysis of the third subspecies was somewhat more complicated.

(a) 400 grains of the pulverized ore were digested with nitric acid, till every thing soluble in this fluid had been taken up.

(b) The nitrous solution was combined with muriatic acid, as long as any precipitation took place; by this there was obtained 51 grs. of a white powder, of which 43 grs. were again resoluble in boiling water. The insoluble portion, amounting to 8 grs. was muriated *silver*.

(c) The solution containing the 43 grs. above mentioned, was concentrated by gradual evaporation, and afforded delicate needleform crystals of muriated *lead*.

(d) The residue of *a*, insoluble in nitric acid, was then treated with nitro-muriatic acid, as long as any thing was taken up: the solution was mixed with the nitro-muriatic solution *b*, and reduced by evaporation till it ceased to deposit muriat of *lead*: 11 grs. were thus obtained.

(e) To the concentrated solution *d*, was added caustic potash in excess, which threw down a copious blackish-brown precipitate; this being separated, the alkaline liquor was saturated with muriatic acid, and the white precipitate thus obtained being again dissolved in muriatic acid, and then precipitated by means of a stick of zinc, afforded 85 grs. of metallic *Tellurium*.

(f) The blackish-brown precipitate of *e* was dissolved in nitro-muriatic acid, and the liquor was nearly saturated with caustic potash; nitrated mercury was then added, till the precipitate began to be white. This precipitate being separated by the filter, and washed, the filter, with its contents, was ignited in a crucible, and a little nitre being added, the fire was increased, and a button of pure *gold* was thus obtained, weighing 50.75 grs.

(g) The remainder of the nitro-muriatic solution *f* was saturated with carbonated potash, and a precipitate was obtained, consisting of oxyd of *manganese*, mixed with carbonated *lime* and a little *alumine* and oxyd of *iron*.

(h) The insoluble residue of *d*, weighing 120.5 grs. and consisting chiefly of quartz, was gently heated, by which it lost about 1 gr. which was *sulphur*: being then mixed with four times its weight of carbonated potash, and fused, there was obtained a button of *silver*, weighing 10.125 grs.

The fourth subspecies was analysed in the following manner.

(a) 1000 grs. of the pulverized ore were digested with 10 oz. of muriatic acid, to which was added, by degrees, a little nitric acid: this being poured off, 5 oz. more of muriatic acid were added, by which every thing soluble in this menstruum was taken up: to the filtered solution boiling water was added, to re-dissolve the muriat of lead which had begun to be deposited.

(b) Of the insoluble residue a part had cohered into a mass, and was for the most part sulphur, weighing 17.5 grs.; being gently ignited, it left behind 3.5 grs. of a blackish matter which was dissolved in muriatic acid, and added to the foregoing solution. Hence the *sulphur* of the ore amounted to 14 grs.

(c) The remainder of the insoluble residue was for the most part quartz, and weighed 440.5 grs. Being melted with four times its weight of carbonated potash, there appeared, on breaking the mass, a few globules of silver, amounting to about 2.5 grs. equivalent to 3.5 grs. of muriated silver; so that the quartzoze matrix was equal to 437 grs.

(d) The solution *a* being concentrated by evaporation, crystals of muriated *lead* were deposited, to the amount of 330 grs. equivalent to 248 of metallic lead.

(*e*) Having thus separated the lead, the remainder of the solution was largely diluted with alcohol, by which a white oxyd of *Tellurium* was thrown down. This oxyd being redissolved by muriatic acid, and again precipitated by caustic soda, afforded 178 grs. of oxyd, equivalent to 148 grs. of reguline tellurium.

(*f*) The alcoholic solution was next distilled by which the alcohol was separated; the residual fluid being diluted with water, was treated with nitrat of mercury, in the way already described, by which a button of *gold*, weighing 41.5 grs. was obtained.

(*g*) The residual fluid of *f* was saturated with carbonated soda and boiled, by which a bluish-grey precipitate was obtained: by digestion in muriatic acid it dissolved, and oxymuriatic acid gas was produced: the muriatic solution being then super-saturated with carbonated ammonia, there was deposited carbonated *manganese*, mixed with iron, to the amount of 92 grs.

(*h*) The ammoniacal solution was of a blue colour, upon which it was super-saturated with sulphuric acid, and a plate of iron being immersed in the fluid, there was deposited 6 grs. of *copper*.

§ 3. *Physical and Chemical Properties*.

Reguline tellurium may be obtained by heating the white oxyd of this metal in contact with carbonaceous matter: but as tellurium is both easily volatilizable and readily inflammable, certain precautions are necessary to ensure the success of the experiment. If the reduction is attempted in a crucible, in proportion as the metal is deoxydated, it rises in vapours through the luting, and burns with a blue flame; so that by the time the oxyd is reduced, the metal will have escaped. In order to succeed perfectly, the following method must be pursued: the oxyd, being previously well mixed with 8 or 9 per cent. of charcoal powder, is to be put into a small glass retort with a receiver adapted, and heated gradually to a low state of ignition: as soon as it arrives at this point, a sudden and considerable production of carbonic acid takes place, a little of the mixture passes into the receiver, and metallic globules will be observed adhering to the neck of the retort, as in the distillation of mercury. The apparatus being then cooled slowly, the tellurium will be found at the bottom of the vessel, with a clean bright crystalline surface, perfectly reduced and unmixed with charcoal. 100 parts of white oxyd afford about 83 parts of metal.

The colour of pure tellurium is tin-white, passing into lead-grey: it has a brilliant metallic lustre: its fracture is straight foliated, and by slow cooling it is superficially crystallized: the form of its crystals however has not been ascertained. It is very brittle, and easily pulverizable. Its sp. gr. is = 6.115. It melts at nearly the same temperature as zinc does; and when ignited it begins to be volatilized. By exposure to the blow-pipe on charcoal, it inflames with a violence approaching to detonation, burning with a vivid blue flame, light-green on the edges, accompanied by a heavy white smoke, which is the oxyd produced by the combustion.

Tellurium combines readily by fusion with its own weight of sulphur, and the result is a lead-coloured striated mass, with a metallic lustre. By ignition in a retort, a part of the sulphur sublimes, carrying with it a small proportion of metal, by which it acquires a blackish-brown colour.

Nitric acid dissolves tellurium, and the result is a clear colourless solution, capable of affording, by concentration and cooling, slender needle-shaped crystals.

Nitrat of tellurium is not decomposable by water.

Muriatic acid by itself has little or no action on tellurium, but when assisted by a small proportion of nitric acid, the solution goes on rapidly. The result is a clear colourless solution, from which a white muriated oxyd, or submuriat, is precipitable on the addition of water; in a larger proportion, however, of this fluid, it is again soluble. If, on the other hand, the concentrated muriat is diluted with alcohol instead of water, no tellurium remains in solution.

Concentrated sulphuric acid, by digestion without heat, takes up a small portion of tellurium, and acquires thereby a deep amethystine red colour. On the addition of a little water, a black flocculent precipitate takes place, and the solution loses its colour. The colour of the solution is likewise destroyed by mere heat, a white oxyd being separated.

If, however, the sulphuric acid is previously diluted with water, and mixed with a few drops of nitric acid, a considerable portion of tellurium is taken up, and the solution is without colour, and not decomposable by the addition of water.

The acid solutions of tellurium are all decomposed by the alkalies; but if these last are added in excess, the oxyd is again taken up, whether a pure or carbonated alkali is made use of.

Pruffiat of potafh, if pure, does not decompofe the falts of tellurium.

The alkaline hydro-fulphurets throw it down in the form of a black powder.

Tincture of galls produces a flocculent pale yellowifh brown precipitate.

Zinc and iron precipitate tellurium in its metallic ftate from all its acid folutions. Tin and antimony likewife decompofe, in a fimilar manner, the muriat of this metal. Phofphorus alfo feparates the metal from its muriatic folution.

The white oxyd of tellurium, if heated by the blowpipe on charcoal, is reduced with a rapid effervefcence to the metallic ftate, and is immediately after volatilized by combuftion, and converted again to an oxyd. If, on the other hand, it be treated without any inflammable matter in a retort, it fufes into a pale yellow ftriated mafs.

Tellurium is not made any ufe of, either in the metallic or in any other ftate.

TERRA FOLIATA TARTARI. See ACETITE *of Potafh*.

TERRA FOLIATA CRYSTALLIZATA. See ACETITE *of Soda*.

TERRA JAPONICA. See CATECHU.

TERRA MERITA. See TURMERIC.

THERMOMETER. *See the Appendix*.

THONSCHIEFER. ARGILLACEOUS SCHISTUS. SLATE. ARGILLITE.

This mineral may be divided into the three following fubfpecies.

1 *Subfp*. Common argillaceous fchiftus.—*Thonfchiefer*, Wern. *Argillite*, Kirw. *Schifte argilleux*, Broch.

Its colour is fmoke-grey, bluifh or afh-grey, greenifh, reddifh, or blackifh grey; fometimes alfo flefh-red, reddifh-brown, yellowifh-brown, or olive-yellow. The colour is for the moft part uniform, but it fometimes prefents fpots, bands, and dendritical delineations. It occurs in mafs, diffeminated, or in rounded fragments. Its luftre is filky or refinous, and varies from glimmering to flightly fhining. Its fracture is flaty, generally ftrait, but fometimes curved or undulating; fome varieties are fo compact as to prefent a dull earthy fracture. Its fragments are tabular or rhomboidal, rarely large fplintery. It varies from very foft to moderately hard, but even the hardeft may readily be fcratched by a knife. It is eafily frangible, but not very brittle. It gives a greyifh-white ftreak.

It is compofed of filex, alumine, and oxyd of iron, with variable proportions of carbonated lime and magnefia. It is largely ufed for covering houfes, and the ftrait-foliated bluifh-grey varieties are employed as writing flates. The fofter and more compact varieties are made into flate pencils.

2 *Subfp*. Hone flate.—*Novaculite*, Kirw. *Wetzfchiefer*, Wern. *Schifte a aiguifer*, Broch. Its colour is greenifh-grey, or fmoke-grey, paffing into olive and mountain-green. It occurs in mafs, and has a glimmering luftre. Its fracture in the great is flaty, in the fmall fplintery. Its fragments are tabular. It is more or lefs tranflucent on the edges. It is moderately hard, and not very frangible. Sp. gr. 2.72.

It does not effervefce with acids, neither is it fufible by the blow-pipe without addition. It has not been regularly analyfed.

It is cut into hones for fharpening the finer kinds of fteel inftruments.

It occurs at Lauenftein in Bareith, at Seifendorf in Saxony, in Bohemia, and the Levant (whence it is called Turkifh hone); alfo in the valley of Llanberris in North Wales.

3 *Subfp*. Black chalk.—*Zeichenfchiefer*, Wern. *Schifte a deffiner*, Broch.

Its colour is greyifh or bluifh-black. It occurs in mafs; the longitudinal fracture is flaty and glimmering, the crofs fracture earthy and dull. Its fragments are tabular or fplintery. It ftains the fingers, and gives a fomewhat gloffy grey ftreak. It is meagre, but fmooth to the touch; is foft and very eafily frangible.

Before the blow-pipe, without addition, it acquires a thin varnifh, but does not melt. Its component parts, according to an analyfis by Wiegleb, are

64.	Silex
11.25	Alumine
11.	Carbon
2.75	Oxyd of Iron
7.5	Water
96.5	

It is employed for drawing and writing on paper and other materials.

The beft kinds come from Italy; it is alfo met with in Spain, France, Bareith, and the ifland of Ifla in the Hebrides.

Of the above fubfpecies, the firft, namely, common argillaceous fchiftus, is the moft abundant. It belongs both to the primitive, tranfition, and fecondary rocks, and occurs in mountain beds, often of vaft extent. It inclofes and fometimes alternates with beds of chlorite flate, hone flate, alum flate, and black chalk, of which the two former peculiarly characterize the pri-

mitive and transition argillaceous schistus. The primitive appears generally to rest upon micaceous schistus, and is occasionally mixed with quartz, mica, hornblende, black schorl, garnet, pyrites, granular limestone, and calcareous spar. It also contains various metallic ores, either in veins or beds. The quicksilver mines of Idria are in primitive argillite, so is the vast bed of copper and iron pyrites forming the Parys mine in Anglesey.

Transition argillite has not been much examined: the greater part of the slate of North Wales appears to belong to this formation, where it rests upon grünstein, and appears to contain no extraneous minerals, except veins of quartz and calcareous spar, with blende and galena. Secondary argillite contains impressions of organized bodies and figured pyrites: it often rests upon secondary limestone, as is the case in Derbyshire.

THUMERSTEIN. Thumerstone, *Kirw.* Pierre de Thum, *Broch.* Axinite, *Hauy.*

The colour of this mineral is clove-brown, passing into violet-blue, and yellowish or greenish grey. It occurs in mass, disseminated and crystallized. The primitive form of its crystals is a strait rhomboidal prism, the alternate angles of which measure respectively $101\frac{1}{2}°$ and $78\frac{1}{2}°$. The vertical edges of the prism, corresponding with the acute angles, are generally, however, more or less truncated. Sometimes the prisms are so short as to be nearly tabular, and are then often cellularly aggregated. The faces of the primitive crystal are striated, but all the secondary planes are smooth. Externally the crystals have a bright vitreous lustre; internally they are generally glistening. The fracture is small conchoidal, in some varieties passing into splintery and fine-grained uneven. When in mass, it is usually composed of thin testaceous distinct concretions. It varies from semitransparent to translucent on the edges. Its hardness is nearly equal to that of quartz; it is brittle and very easily frangible. Sp. gr. 3.2 to 3.3.

It melts before the blowpipe without addition into a greenish white semitransparent glass; but on charcoal to a black glass. It has been analysed by Klaproth [a] and Vauquelin [b], with the following results.

	Klapr.		Vauq.
Silex - - -	52.7	—	44.
Alumine - -	25.6	—	18.
Lime - - -	9.4	—	19.
Oxyd of Iron -	9.	—	14.
Ditto Manganese	0.6	—	4.
	97.3		99

The proportions of this mineral as stated by the two able chemists just mentioned, differ from each other very considerably, and on comparing the methods pursued by each in performing the analysis, it will we believe, be generally allowed that Vauquelin's is the least subject to error. With regard, however, to the oxyd of iron, the difference is more apparent than real, Klaproth stating it as magnetic oxyd, and Vauquelin as red oxyd; whereas, if in each analysis it was brought to the latter state, Klaproth's 9 grs. should be raised to 12.6 grs.

Thumerstein occurs only in primitive mountains, and is accompanied by asbestos, actynolite, calcareous spar, quartz, felspar, and sometimes with sulphur, arsenical pyrites, and native bismuth. The massive variety is met with at Thum in Saxony (whence is derived the German name of this mineral.) It occurs crystallized near Oisans in Dauphiné, at Kongsberg in Norway; also in Spain, Savoy, and Cornwall.

TIN. Zinn, *Germ.* Etain, *Fr.*

Tin is a metal of a silver-white colour, very ductile and malleable, gives out while bending a peculiar crackling noise, is fusible at a heat much less than that of ignition: is slowly soluble in muriatic acid, and by dilute nitric acid is rapidly converted into a white oxyd.

§ 1. *Ores.*

Sp. 1. TINSTONE. Zinnstein, *Wern.* Pierre de Etain. Mine d'Etain commune, *Broch.*

Its usual colour is brownish-black, passing into clove-brown, blackish, redish or yellowish-brown: sometimes also it occurs wine-yellow, smoke-grey, yellowish-grey and greyish-white. It occurs in mass, disseminated, in rounded fragments, and crystallized. Its primitive form is suspected by Hauy to be the cube: the forms under which it actually appears are,

1. A rectangular tetrahedral prism, terminated at each extremity by a tetrahedral pyramid, the faces of which are isosceles triangles.

2. The preceding, with the longitudinal edges of the prism truncated.

3. Var. 1. with the longitudinal edges both of the prism and pyramid truncated, whence results an eight sided prism, with eight sided summits, the faces of which latter are alternately triangles and pentagons. Sometimes the prism is doubly truncated, and then presents sixteen sides, the terminating pyramids remaining as before.

4. A strait eight-sided prism similar to the foregoing, with the terminal pyramids very deeply truncated.

[a] Anal. Ess. Vol. I. p. 413. [b] Journ. des Mines, No. 23. p. 1

5. A rectangular tetrahedral prism terminated at each extremity by a tetrahedral pyramid, the faces of which are rhombs.

6. The foregoing, with those edges of the terminal pyramid that are adjacent to the prism deeply truncated.

7. Similar to the foregoing, only the terminal pyramid is much higher, and the lateral truncatures are so deep as to obliterate the original rhomboidal faces, whence results a pyramid composed of eight trapeziums.

8. The same as the preceeding, with the points of the terminal pyramid truncated and replaced by a low eight-sided pyramid, composed of alternate trapeziums and long hexagons.

9. A crystal originating from var. 1. in which an oblique section appears to have been made, and the two portions turned half round on each other, so as to form at each extremity two re-entering angles. These half-turned or hemitrope crystals are of particularly frequent occurence.

The crystals vary much in size but are seldom large, and are almost always half-imbedded and grouped together in a confused manner. Externally they are commonly smooth, sometimes striated, and exhibit a bright, almost vitreous lustre. Internally they are shining or glistening, with a lustre between resinous and vitreous. The fracture is small-grained uneven, sometimes imperfectly conchoidal, and rarely lamellar. The massive varieties present granular distinct concretions. It varies from semitransparent to opake; gives a greyish-white streak; is hard, affording sparks when struck by the steel, is brittle and easily frangible. Sp. gr. 6.7 — 6.97.

Before the blowpipe on charcoal it decrepitates, becomes pale and opake, and is in part reduced to the metallic state. It has been analysed by Klaproth and Lampadius with the following results.

Klapr. from Alternon.		Lampad. Ehrenfriedersdorf.	
77.5	—	68.	Tin
21.5	—	16.	Oxygen
0.25	—	9.	Oxyd of Iron
0.75	—	7.	Silex
100 . .		100.	

Tinstone occurs only in the oldest of the primitive rocks, as granite, gneiss, micaceous schistus, and some varieties of argillaceous schistus, either in veins, or beds, or disseminated. It is accompanied by quartz, mica, lithomarga, talc, steatite, fluor spar, chlorite, topaz, apatite, wolfram, arsenical pyrites, &c. It occurs also in rounded fragments in alluvial beds, forming the shode and stream tin of Cornwall.

It is found in Cornwall, in Gallicia in Spain, in the Erzgebirge on the borders of Saxony and Bohemia; in the peninsula of Malacca and the island of Banca in Asia, and in Chili in South America.

It is the only ore of tin sufficiently abundant to be worked.

Sp. 2. Wood Tin. Kornisches Zinnerz, *Wern.* Mine d'Etain grenue, *Broch.*

Its colour is hair-brown of different shades, passing into yellowish-grey and Isabella-yellow; two or more colours are often arranged in parallel bands in the same specimen. It has hitherto been found only in small rolled pieces, which sometimes are reniform, and this is probably the original form of this mineral. Externally it is rough and glistening; internally it has a glimmering somewhat silky lustre. Its fracture is finely fibrous, either straight, bundled, or diverging. Its fragments are wedge-shaped or splintery. It occurs in large and coarse granular distinct concretions, which are themselves arranged in thin curved lamellæ. It gives a shining yellowish-brown streak. It is opake, hard, brittle, and easily frangible. Sp. gr. 6.45.

Before the blowpipe it becomes brownish red and decrepitates, but is not fused or reduced to the metallic state. When strongly heated in a charcoal crucible, it affords according to Klaproth about 73 per cent. of reguline tin.

This mineral has hitherto been found only in Cornwall, in the parishes of St. Columb, St. Roach, and St. Dennis, in alluvial beds accompanied by tinstone. It is rare, and occurs only in small pieces.

Sp. 3. Bell-metal ore. Tin pyrites. Zinnkies, *Wern.* Etain pyriteux, *Broch.*

Its colour is steel-grey, with a tinge of brass-yellow, passing into yellowish-white. It occurs in mass and disseminated. Internally it has a weakly-shining metallic lustre. Its fracture is granular uneven, passing into small conchoidal, and rarely, imperfectly lamellar. Its fragments are indeterminate, blunt edged. It may easily be scratched by a knife, is very brittle and easily frangible. Sp. gr. 4.35.

Before the blowpipe it gives out a sulphureous odour, and fuses easily into a blackish slag. It tinges borax of a yellowish green colour.

The proportion of tin which it contains is

ſubject to conſiderable variation: the lighter is its colour and the greater is the proportion of this metal. A ſpecimen of this kind was compoſed, according to an analyſis by Klaproth, of

34	Tin
36	Copper
25	Sulphur
2	Iron
97	

It has hitherto been found only at Wheal Roch, in the pariſh of St. Agnes in Cornwall, in a vein about nine feet wide, accompanied by blende and copper pyrites.

§ 2. *Aſſay and Analyſis.*

The aſſay of tin ore is extremely ſimple. Being firſt reduced by pounding to the conſiſtence of coarſe ſand, it is ſeparated by waſhing from the ſtony matters with which it is mixed (a proceſs that may be performed with great accuracy on account of the high ſpecific gravity of the ore). A grain or two is then to be treated by the blowpipe in order to aſcertain whether any arſenic is preſent. If this is the caſe, 200 grains of the ore mixed with a little charcoal, are roaſted in a calcining teſt at a low red heat, till no arſenical vapours are any longer to be perceived; the reſidue being withdrawn from the fire is to be mixed with a little pitch and fine ſaw-duſt, and put into a crucible lined with charcoal; a cover being luted on, it is to be placed in a wind or forge furnace (the latter is the beſt) and pretty rapidly raiſed to a bright red heat: in a quarter of an hour or twenty minutes the reduction will be compleated, the crucible being then removed from the fire and cooled, there will be found in it a button of metallic tin, either entirely free from ſcoriæ, or at moſt covered with a very thin blackiſh cruſt, which may be removed by gentle hammering.

If the ore on trial with the blowpipe appear to be entirely free from arſenic, the roaſting may be omitted.

The analyſis in the moiſt way though ſomewhat more complicated, is yet upon the whole ſufficiently ſimple. The method attempted by Bergman and others, of analyſing the ores of tin by means of acids, is extremely unſatisfactory, little or nothing but the impurities being taken up by theſe menſtrua. The proper mode of treating theſe ores is by means of the fixed alkalies;[b] the diſcovery of which forms one of the numerous obligations conferred by Klaproth on analytical chemiſtry.

Tinſtone.

Specimens of this mineral from Cornwall and Bohemia were thus analyſed by Klaproth.

(*a*) 100 grs. in cryſtals were ground to a fine powder, and added to a lixivium containing 600 grs. of cauſtic potaſh. This mixture was evaporated, and then moderately ignited for half an hour in a ſilver crucible; a greyiſh-white maſs was thus obtained, to which, while yet warm, was added boiling water, which diſſolved the whole with the exception of 11 grs.

(*b*) Theſe 11 grs. were again ignited with ſix times their weight of cauſtic potaſh, and being digeſted in boiling water there remained behind only 1¼ gr. of a fine yellowiſh-grey powder.

(*c*) The alkaline ſolutions being mixed together, muriatic acid was added to ſaturation, upon which a white oxyd of tin fell down: this was rediſſolved by an exceſs of muriatic acid, and finally precipitated by carbonated ſoda. This precipitate when waſhed and dried at a gentle heat, appeared in the form of tranſparent yellowiſh lumps, with a vitreous fracture.

(*d*) This precipitate being pulverized was diſſolved in muriatic acid, and into the ſolution, previouſly diluted with two or three parts of water, was inſerted a ſtick of zinc, by which the tin was thrown down in the form of thin metallic laminæ. Theſe being waſhed and dried were fuſed in a ſmall crucible under a cover of melted tallow, and afforded a metallic button weighing 77 grs.

(*e*) The reſidue of *b* amounting to 1¼ gr. was treated with muriatic acid, with which it formed a yellowiſh ſolution: from this 0.5 gr. of tin was ſeparated by means of zinc. The remainder afforded a light blue precipitate with pruſſiat of potaſh, indicating not more than 0.25 gr. of oxyd of iron: about 0.75 gr. of ſilex was alſo procured. By adding theſe products together, and making no allowance for loſs, there will remain 21.5 grs. for the oxygen contained in the ore.

Wood-Tin is to be analyſed in the ſame manner as the preceding.

Bell Metal Ore.

This was treated by Klaproth in the following manner.

(*a*) 120 grs. being reduced to a fine powder, were digeſted in the cold for 24 hours with aqua regia, compoſed of two parts muriatic and one part nitric acids: the mixture was then digeſted for ſome time longer on a ſand

[b] Klapr. Analyſ. Vol. I. p. 522.

bath. When the acid had entirely ceafed to act, the folution was diluted with water and filtered; 43 grs. remained undiffolved, from which by gentle ignition on a teft there were feparated 30 grains of fulphur. The refidue, amounting to 13 grs. was digefted in nitro-muriatic acid, by which 8 grs. were taken up. The remaining 5 grs. confifted of about 3 grs. of filex, and 1 gr. of iron, reduced to the ftate of magnetic oxyd by roafting with wax.

b. The acid folutions being mixed together, carbonat of potafh was added to faturation, by which there was obtained a dirty-green precipitate, which by fubfequent folution in muriatic acid afforded a green fluid. A cylinder of pure tin weighing 217 grs. was immerfed into the folution till it became quite colourlefs, in confequence of the precipitation of 44 grains of reguline copper.

c. This copper by brifk digeftion in nitric acid left behind a little white oxyd equivalent to 1 grain of tin; hence the true amount of copper is equal to 43 grs.

d. The cylinder of tin during its digeftion in the folution *b*, had loft 89 grs. This folution was now decompofed by a cylinder of zinc, and the metallic precipitate when wafhed and dried was mixed with tallow and charcoal powder, and moderately heated in a crucible; there were thus obtained, 1 gr. of magnetic oxyd of iron and 129 grs. of reguline tin, from which deducting 89 grs. as belonging to the cylinder, there remain 30 grs. for the amount of tin in the ore.

§. 3. *Reduction of Ores.*

The method of treating the ores of tin in Cornwall is two-fold.[c] The firft that we fhall mention is that to which the tinftone from the mines or vein-tin is fubjected; the fecond is that by which the ftream tin is reduced.

1. The vein-tin is procured by blafting, and when brought to the top of the pit is in fragments of various fizes, and mixed fo largely with quartz, argillaceous fchiftus, granite, and other impurities as rarely to contain more than 2 per cent. of metal. The firft preparation that it receives is being broken by hand hammers into pieces about the fize of hens' eggs, after which it is ready to be ftamped. The ftamping-mill is of the ufual conftruction (fee the article GOLD) except that the ftampers are only three in number, and in front of the trough or coffer there is inferted a plate of tin about a foot fquare, pierced full of holes, large enough to admit a moderate fized knitting-needle; that furface of the plates which is occupied by the *rough* extremities of the holes is placed on the infide of the trough, by which fimple and effectual contrivance the holes are prevented from being plugged up by the ore. In proportion as the tin-ftone is reduced to the proper degree of finenefs it paffes with the water through thefe holes into a labyrinth of very fimple conftruction; here the oxyd of tin is feparated from much of the lighter impurities, and by fubfequent wafhing on a wooden table it is fufficiently dreffed to be fent to the roafting furnace; in this ftate it is called *black tin*, and is generally mixed in confiderable proportion with mifpickel, and iron and copper pyrites. It is now calcined at a low red heat in a large reverberatory furnace for feveral hours in order to volatilize the arfenic and burn off the fulphur, (a part of this laft after being acidified, combines with the oxyds of copper and iron). The ore comes out of the roafting furnace of a bright ochery red colour, owing to the decompofition and oxydation of the pyrites and mifpickel, the oxyd of tin, if the operation has been well performed having undergone not the leaft alteration. The ore is now wafhed a fecond time, by which nearly the whole of the impurities are feparated. The water employed in this procefs being confiderably impregnated with fulphat of copper is referved, and afterwards decompofed by the addition of pieces of old iron. The next ftep is the reduction, properly fpeaking; for this purpofe a reverberatory furnace, about 7 feet long and 3½ feet wide, is charged with 7 cwt. of roafted ore mixed with ⅕ of its *bulk* of culm (Welch fmall-coal) no lime or any other kind of flux being made ufe of; the fire is kept up pretty brifk for about fix hours, and the tin in proportion as it is reduced finks down to the bed of the furnace, being covered with a boiling hot bath of black fcoriæ. At the expiration of this period the furnace is tapped by means of an iron bar, and the hot metal flows into a fhallow pit at the foot of the furnace. When the whole of the metal has run out, the fcoriæ are drawn out of the furnace with a rake, and a frefh charge is immediately thrown in. While the metal in the pit is red hot it throws up a quantity of flag very rich in metal, which is immediately returned into the furnace, and the melted tin after it has become fufficiently cool is taken out with iron ladles and poured into moulds of granite, where it confolidates, each charge affording on an average from 4 to 5 cwt. of metal. The firft

[c] Original Communication.

ſcoriæ are not entirely exhauſted of metal, and are therefore transferred to the ſtamping-mill, and afterwards waſhed, in order to ſeparate the richer particles, which are then mixed with the next parcel of roaſted ore.

The pigs of tin thus procured are next put without any addition, into a ſmall reverberatory furnace where they are expoſed to a very gentle heat, the pureſt part of the tin firſt melts and is drawn off, forming the common grain tin; the more refractory part containing a ſmall but variable portion of copper, arſenic, and iron, is then brought to a ſtate of fuſion, and caſt into pigs forming the common or ordinary tin.

2. The ſtream tinſtone is not, we believe, found in any other part of Europe than Cornwall. It differs from the former in its extreme purity and abſolute freedom from arſenic, and in its occurring in alluvial beds. The largeſt ſtream-tin work is at Carn, about two miles to the S. E. of Perran, not far from Redruth. It is ſituated in a valley, through which flows a ſtream, the courſe of which has been turned for the ſake of getting at the treaſure concealed beneath its bed. The workmen firſt dig through a ſtratum about fifty feet thick of clay, ſhells, and black earth, in which have been found hazel nuts, the antlers of an animal of the ſtag kind, a human ſcull, and a copper battle-axe; to this ſucceeds a layer of rounded ſtones, beneath which is the bed of tin ore in grains and lumps of various ſizes. The thickneſs of this bed varies from one to five feet, but the thickeſt part is comparatively the pooreſt. The whole of the ſuperincumbent ſtrata is cut away as the workmen proceed, ſo that the general appearance of the cavity is that of a vaſt gravel or ſand pit, near half a mile long, and about 200 feet broad, which is kept clear of water by the powerful action of two water-mill pumps. The tin ore, as it lies quite looſe, is merely ſhovelled into barrows, and wheeled to the head of the works, where it is thrown under a thin ſheet of water which waſhes away the earth, leaving the pure ore behind. After this ſimple purification the ore is ſent to St. Auſtle, a diſtance of about twenty miles, to be ſmelted. Here all the preparation for the furnace that it receives is being bruiſed and paſſed through wire ſieves containing ſixteen meſhes in the ſquare inch. The furnace employed is called in Cornwall a *blowing furnace*, and is in fact only a blaſt furnace of the ſimpleſt conſtruction, about ſeven feet high, and ſupplied with air from two cylinders, worked by an overſhot water-wheel. The only fuel made uſe of is *charcoal*, and after the furnace is fully heated it is fed at ſhort intervals with the following charge, viz. three or four ſhovelfuls of ore, and two or three half-buſhels of charcoal, no flux of any kind being employed. At the bottom of the furnace is a ſmall channel through which the reduced tin is conſtantly flowing into a pit below, accompanied by a ſmall quantity of ſlag, which is removed from time to time, and thrown again into the furnace. When the pit is full of tin it is ladled out into an iron boiler, about three feet in diameter, with a ſmall fire under it to keep the metal ſufficiently fluid: two or three large pieces of charcoal are then laid upon the tin, and plunged to the bottom by means of an iron inſtrument reſembling a wheel, with a long handle fixed in the axle. A violent ebullition is immediately excited, and a little ſlag, which was before mixed with the metal, riſes to its ſurface, and is ſcummed off. In a minute or two after, the metal is *tried*, by taking up a ladleful and pouring it again into the maſs, when if it appears quite bright like ſilver, and of an uniform conſiſtence, the purification is compleat, and nothing more is requiſite than to cool it to the proper degree, and lade it into the moulds, by which it is formed into pigs, weighing from 2 to 3 cwt. each. If the metal is poured too hot into the moulds it is apt to be brittle. Good ſtream tin affords from 65 to 75 per cent. of the very beſt and pureſt grain tin.

None of the Corniſh tin may be ſold till it has been coined; for this purpoſe a ſmall piece is cut off from every pig and aſſayed; if it appears of the requiſite purity it receives the ſtamp of the Duchy, and pays to the Prince of Wales, as Duke, four ſhillings per cwt.

§. 4. *Phyſical and Chemical Properties.*

Tin is a metal of a beautiful ſilvery whiteneſs when recently melted, but by ſhort expoſure to the air it acquires a ſuperficial tarniſh, which does not much increaſe by time. It has a ſlight and nauſeous taſte, and gives a peculiar ſmell when rubbed. It may be cryſtallized by melting a quantity and pouring out the center of the maſs after the ſides have ſolidified. Its ſpecific gravity is about 7.9. It is an extremely ſoft metal, ſcarcely if at all elaſtic, and when a piece of it is bent backwards and forwards it gives a peculiar crackling noiſe. It has very little tenacity, being in this reſpect inferior even to gold, and only ſuperior to lead. It is ex-

tremely malleable, and may readily be extended into leaves thinner than writing paper. It is the most fusible of all the solid metals, and melts at about 442° Fahr.

It is reduced to powder for medicinal purposes by being melted and poured into a wooden box, rubbed with chalk on the inside, and shaken violently, and afterwards washed to get rid of the chalk.

It is not rusted nor apparently altered by being kept under water.

The oxydation of tin when heated in contact with air has been much examined by chemists. When this metal is melted in any open vessel, as soon as the fusion is compleat, the surface tarnishes and wrinkles, forming a firm pellicle of a dusky grey colour, and if these pellicles are successively removed as they form, the whole metal is gradually changed into them. If the whole mass is then rubbed in a mortar with water, and the liquid immediately decanted to separate some uncalcined particles of tin which remain entangled in the pellicles, an uniform grey-brown oxyd is produced, in which the microscope can discover no particles of reguline metal, and which is tin in the first or lowest state of oxydation. During the first calcination the heat should not be raised quite to redness.

If this first oxyd is then again heated, with constant stirring, in a broad vessel made fully red-hot, the colour of the oxyd gradually changes to an uniform light grey, which, by continuing the heat for some time, becomes white, harder, and somewhat agglutinates, but undergoes no further alteration. If the first oxyd is heated pretty briskly in this process, it becomes very luminous, and actually burns with a bright flame during its further oxydation. The combustion of tin is also shewn more distinctly by heating a quantity of the metal immediately to a full red or white heat in a covered crucible, and then on removing the cover and turning aside the crust of oxyd on the surface, the metal will burn with a very vivid flame somewhat like zinc, and an immediate and copious sublimation of white oxyd. The same effect is shewn more speedily by heating intensely a little tin with the blow-pipe on charcoal, and then on suddenly throwing it down on a hearth, it disperses into a number of beautiful luminous globules.

Whilst tin is in the act of combustion, the oxyd which is formed in the process acquires a volatility, and visibly sublimes when the heat is very intense, but when the oxyd is already formed, it is perfectly fixed in the fire, and is with difficulty fusible *per se* in the utmost intensity of fire. Thus as Geoffroy has observed[d] if tin be placed *on charcoal*, and the focus of a powerful burning glass thrown on it, it insensibly dissipates in smoke without any residue; but if placed on an *earthen* support it first burns for a while with evident smoke, after which a thick white crust of oxyd forms on the surface, which by continuing the heat takes the form of small hard transparent crystals.

The phenomena that occur on heating tin very intensely are shewn by an experiment of Beaumé. He put some Malacca tin in a crucible, inclosed this in a muffle, and exposed the whole to a very strong heat for two hours. When cold, the upper part of the crucible was found covered with a considerable quantity of flowers of tin of extreme whiteness and symmetrically arranged in brilliant needles. Beneath this were many vegetations of oxyd of tin of a cauliflower form, considerably hard, and of a brick red. Below this was an incohering mass of pure white oxyd of tin; under which was a stratum of clean transparent glass, or vitrified oxyd, of a bright garnet red; and below the latter was a portion of the reguline metal unaltered.

From all the experiments that have been made on this subject it appears that there are at least two distinct degrees of oxydation of tin effected by the joint action of heat and air, the lowest of which is formed at a heat below redness, and produces a dusky grey oxyd; and the highest, which is formed at a full red heat and with visible combustion, produces an oxyd which is nearly white. The latter, when heated very intensely, appears capable of fusion, though with much more difficulty than the oxyds of iron, lead, and copper. With regard to the red, yellow, and green shades of colour, which the fused oxyd of tin sometimes assumes, this may partly be attributed to a casual admixture of the above metals; but if the tin was nearly pure in Beaumé's experiment, the colour of the pure vitrified oxyd of tin is a garnet red. This however does not agree with Klaproth's experiments, who found the purest native oxyds of tin, containing no more than a quarter per cent. of oxyd of iron, when fused in a clay crucible in a porcelain furnace to run into a clear glass, either greenish-grey or with a slight tinge of yellow, but with no tendency to the garnet-red hue. When the oxyd of tin, either

[d] Mem. de l'Acad. for 1738, p. 115.

by itself or mixed with the oxyd of lead is fused with the saline and earthy vitrescent mixtures it gives a beautiful opake white, as we have already mentioned under the article *Enamel*. It is doubtful however whether in this process the oxyd of tin is brought to compleat fusion, and whether the opacity does not arise from this circumstance.

It is somewhat doubtful whether there is any distinct intermediate oxyd of tin between the two that we have mentioned, or whether the successive shades of colour which the first oxyd assumes during its compleat calcination, are not owing to a mixture of the perfect with the imperfect oxyd.

A preparation of the oxyd of tin is made for the purpose of giving the highest polish to steel, and to glass and metal mirrors, which is called *Tin Putty*. It is prepared according to Beaumé in the following way.

Some tin is melted in an iron vessel with a low red heat, and the oxyd that forms on the surface is successively removed till enough of it is procured. This is then spread on a red-hot muffle, and heated for half an hour, with frequent stirring, to compleat the calcination of any particles of tin that may be entangled in the oxyd. When cold it is powdered and sifted, and the finer part is again calcined for six or seven hours on a muffle with a stronger heat, till it becomes almost white, and considerably hard, and in this state it forms the tin putty.

This substance is made in this country in a similar way. For the finest putty the purest grain tin is employed, which is calcined in a muffle, finely levigated, and washed. This is nearly white, but the ordinary and cheaper sorts are browner, and are made by calcining old pewter, or else a mixture of tin and lead, or any other alloy of these metals, which when in mixture oxydate still more readily than either of the metals separately, and will easily take fire as soon as the heat is raised to redness. As the oxyd of lead is very fusible, and the oxyd of tin very little so, the subsequent calcination in this case is probably made at a lower heat than when pure tin is used, otherwise the whole would run into a dense glass. This preparation must not be confounded with glazier's putty, which is only chalk beat up with linseed oil.

Tin is readily oxydated by nitre in the following way. Project a little of this salt on tin made moderately red-hot in a crucible. A very strong deflagration ensues, with a brilliant white flame and a dense white smoke, which latter consists of part of the oxyd of tin volatilized, and will settle on the adjacent surfaces in the form of a fine white powder. Continue to project small quantities of nitre on the tin as long as any effect is produced (the heat being kept up to full redness) by which the whole of the metal is oxydated in the highest degree. When cold, dissolve out all the soluble part of the contents of the vessel, and a very pure white oxyd of tin will be left behind, which is sometimes used as the base for opake enamel colours, though this in general is a mixture of the oxyds of tin and lead made by calcination. The soluble part of the residue from the deflagration of tin and nitre, consists of the undecomposed nitre, if any, together with the potash of the portion which has been decomposed, in a caustic state, and holding a considerable quantity of the same oxyd of tin in solution, which may be separated by saturation with an acid. This oxyd of tin by nitre may be prepared rather more conveniently by previously mixing together one part of tin filings with three parts of nitre, and projecting the mixture by spoonfuls into a crucible made very hot. The grey oxyd with a smaller quantity of nitre will answer equally well.

It does not appear that an exact analysis has been made of the different oxyds of tin formed by the mere action of fire and air, but the white oxyd, which is that formed by compleat combustion at a strong heat, is probably at the highest state of oxygenation, and therefore in its composition resembles the perfect oxyd made by nitric acid, which will be presently mentioned.

A very marked difference is found in the chemical properties of the higher and lower oxyds of tin. The grey oxyd (or *sub-oxyd* as it may be termed for distinction) made by calcination at a low heat, takes fire when brought to a full red, and assumes a white colour with increase of oxydation—it detonates with nitre, and is thus converted to the higher oxyd—it dissolves in muriatic acid with emission of hydrogen, and in dilute nitric acid—when in solution it gives a black brown precipitate with sulphuret of potash, and a black with corrosive mercurial muriat—and it is reduced to the metallic state again with the utmost ease, by being moderately heated with pitch, charcoal, or any carbonaceous matter. On the other hand, the *white or perfect oxyd* is not further changed by the action of fire except being fused by it when very intense, during which it again loses part

of its oxygen—excites no deflagration with nitre—is insoluble in dilute nitric acid—and is not readily reduced to the metallic state. There are besides several other important differences between the salts and compounds of these two oxyds, as will be seen further.

Sulphuric acid diluted with about a fourth part of water, will dissolve about a quarter of its weight of tin, when this metal is added in small grains or filings, and the solution assisted by a moderate heat. An effervescence of sulphurous acid vapour arises, and sometimes sulphur in substance is produced[e] from the total decomposition of part of the acid, which swims on the surface of the solution when hot, but subsides on cooling. The colour of this sulphat of tin is yellowish brown, which becomes clear on standing. When saturated it deposits, after a while, needled crystals of sulphat of tin. If the solution is evaporated almost to dryness, it becomes on cooling a white semi-opake mass, which is mostly again soluble in water. When sulphat of tin has been long boiled, a copious white precipitate subsides which will not again dissolve, and consists of the perfect oxyd of tin retaining a small portion of the acid, and is therefore a sub-sulphat. The supernatant liquor on copious dilution with water yields a further quantity of a similar white precipitate, after which scarcely any of the metallic salt remains in the solution. A similar precipitate takes place in a greater length of time by simple exposure of the solution of the sulphat to the air. It is probable therefore that the only permanently soluble state of union between sulphuric acid and tin is when the metal is at an inferior degree of oxydation, and that these precipitations are occasioned chiefly by an increase of oxydation of the metallic salt, which is also analogous to the habitudes of the other salts of this metal. The sulphuric acid when much diluted has no sensible action on tin, but it would probably dissolve its sub-oxyd.

The action of nitric acid upon tin is extremely curious. When this acid, highly concentrated, is poured upon tin filings, no action whatever ensues, but on dilution with a little water a most violent effervescence immediately follows, more violent than with any other metal, a prodigious eruption of nitrous gas takes place, and the metal is speedily reduced to a bulky white powder, which is the perfect oxyd of tin retaining a small portion of the acid. When the action of the acid is over, and the mixture has been diluted with water, and allowed to clear by subsidence, the supernatant liquor is moderately acidulous, but contains scarcely a particle of metal in solution, so that it may be saturated with an alkali with very little change of its transparency; but on evaporation nearly to dryness it deposits in the form of a white oxyd what little of the metal it still retained. Tin may however be dissolved in nitric acid, if it be considerably diluted, without exciting any effervescence. In this state, when the metal is immersed in the acid it gradually falls to pieces in the form of a black powder,[f] which is quietly dissolved in the acid till the whole disappears, or till the acid is saturated. Some heat is given out in the process, which should be checked by putting the vessel in cold water; and to make a saturated solution, the tin should only be added in small quantity at a time.

This solution is yellow, and in a day or two it deposits spontaneously part of its metal in the form of an oxyd, or immediately, if at all heated. Both the solution and the oxyd however contain the metal in the lower state of oxydation, for both the former, and the latter, when redissolved in muriatic acid, precipitate corrosive muriat of mercury black. If nitric acid is added to the solution, and heat applied, a copious effervescence arises, and the whole of the tin separates as white or perfect oxyd. The union between nitric acid and oxyd of tin therefore is very weak and little permanent, and only exists when the metal is in the state of sub-oxyd.

Whenever tin is dissolved or oxydated by nitric acid ammonia is generated, and in very sensible quantity. The production of this alkali is rendered very apparent in the following way. Moisten a few drachms of tin filings with nitric acid somewhat diluted, and in the midst of the effervescence excited thereby add a quantity of quicklime in powder, when on rubbing them together a very pungent smell of volatile alkali will be perceived. In this case the ammonia which is formed, first unites with part of the nitric acid, but is again expelled from it by the lime, and being volatilized is made obvious to the smell. The production of ammonia implies a very complicated action. As this alkali is not contained, as such, in the nitric acid, the water, or the tin, it must be produced by the instantaneous combination of its elements, azot and hydrogen, during the mutual action of these three bodies.

[e] Baumé. [f] Proust J. Phys. tom. 51.

Of these the nitric acid alone can furnish the azot, and the water, the hydrogen; consequently a portion of nitric acid must be totally decomposed into its ultimate constituents, azot and oxygen; and a corresponding portion of the water must be equally resolved into hydrogen and oxygen. This double decomposition therefore, and the union of the azot of the one with the hydrogen of the other to form ammonia, must leave a disposable quantity of oxygen from each, which, as it does not fly off in the form of gas, must be fixed by some of the substances present, which is doubtless the metal in this instance, as it is oxygenated to the highest possible degree, and contains a large quantity of this principle. A great proportion of the oxygen is also furnished by the direct decomposition of the nitric acid, by means of the metal, as is proved by the copious production of nitrous gas, and also of *nitrous-oxyd*, as has been mentioned under that article. The quantity of ammonia generated has been estimated by an experiment of Guyton.[g] He heated, in a retort, two parts of nitric acid with three of tin, diluting the acid largely with water. Though there was a very marked action between the acid and metal, no gas was given out, but the residue contained nitrat of ammonia, of which the ammonia amounted to nearly the twentieth part of the joint weight of the acid and the tin employed.

The white perfect oxyd, produced by the utmost action of nitric acid on tin, is composed, according to Proust, of about 28 per cent. of oxygen and 72 of tin; 100 parts of the metal receiving an increase of 40 by the oxygenation.[h]

Tin dissolves copiously and with ease in muriatic acid. The solution goes on even in the cold, but with much more rapidity when warmed. The muriatic acid immediately loses its yellow colour, a gentle effervescence arises, and a quantity of hydrogen is given out, which has a very peculiar and offensive smell, which has been compared to that of old privies. This has been thought by some to depend on the solution in the hydrogen of a little of the arsenic which most tin contains, forming that peculiar modification of this gas which has been already described under the article *Arsenicated Hydrogen*. However, though it is certain that when arsenic is present some of it may be volatilized by the hydrogen, it does not appear very probable that this is the sole cause of this very peculiar smell of the hydrogen from tin, since the purest possible tin gives the same gas, and therefore we should rather consider it as owing to the volatilization of a minute quantity of the tin itself.

The most concentrated muriatic acid will dissolve, in a boiling heat, more than a quarter of its weight of tin; and a blackish-grey insoluble powder is left behind, which has not been examined. The solution contains an excess of acid, however highly it is saturated with metal, which excess is essential to this muriat when soluble in water. It is perfectly limpid and colourless as water, has a strong styptic and metallic taste, and contains the metal in the lowest state of oxydation. It is therefore properly a *muriated sub-oxyd* of tin; and we shall at present give it this term, to distinguish it from another muriat in which the tin is in a high state of oxydation, and which we may term *muriated super-oxyd*.

Each of these salts has very remarkable and distinguishing properties.

The hot-saturated solution of muriated sub-oxyd deposits, on cooling, an abundance of crystals of the salt, which are generally in the form either of small scales, or of long acicular prisms. A further quantity may be obtained by evaporation. These crystals when redissolved and evaporated again (retaining a slight excess of acid) may be obtained larger and more regular, but by exposure to air the nature of the salt is gradually changed by the absorption of oxygen. The union of the oxyd of tin, in either state, with muriatic acid, is much more permanent than with the nitric or sulphuric acid, so that the solution, when slightly acidulous, may be repeatedly heated and cooled without depositing its oxyd.

The muriated sub-oxyd of tin is distinguished by its possessing an extreme affinity for oxygen, greater than that of any other metallic solution; in consequence of which it deprives of oxygen (partially or totally) all the metallic salts, and many other bodies, which gives rise to an infinite number of curious experiments, the knowledge and true explanation of which is due chiefly to the ingenious labours of Pelletier and Proust.

The following are some of the examples of deoxygenation produced by this muriat; but it should be premised, that as the solution absorbs oxygen even from the atmosphere, it should be kept in a well-closed bottle, and the low degree of oxygenation will be still further insured by keeping some bits of metallic tin immersed in it.

This solution does not affect the sulphuric

[g] Encycl. Method Art. Etain.

[h] J. Phys. tom. 51.

acid; but when added to the sulphureous acid, a considerable heat is excited in a few minutes, and a yellow sulphuretted oxyd of tin is precipitated.

Concentrated nitrous acid, added to the solution of tin, causes an immediate extrication of nitrous gas, so copious as to be almost explosive, and the solution is compleatly oxygenated.

Oxymuriatic acid is instantly deprived of its peculiar pungent smell, by adding a few drops of the solution, and the oxygen of the acid unites with the tin.

White arsenic, and the arsenic acid, digested with the solution, are both decomposed, and a black powder is precipitated, which is arsenic in the metallic state.

The red oxyd of mercury is decomposed immediately by the solution, and corrosive muriat, by gentle heating; and in both cases the metal is totally reduced into globules of running mercury.

The white oxyds of antimony and zinc are reduced by the solution, and assume the metallic form.

The solutions of silver undergo a similar change.

The nitro-muriat of gold, added to this solution, causes that purple precipitate described under the article Gold, and called, after the inventor, Cassius's precipitate.

The solutions of highly-oxygenated iron, such as the red sulphat, are immediately brought by this muriat of tin to that state in which the metal is in the lowest degree of oxygenation, which is the reason why the common yellow muriatic acid, that owes its colour to iron, is rendered colourless as soon as tin is immersed in it. The solutions of copper undergo a similar change.

These phenomena have been already described fully, under the articles *Copper*, *Iron*, and *Prussic acid*.

Hydro-sulphuret of potash gives a black precipitate with this muriat of tin.

Lastly, when a little of this muriat is confined with oxygen gas or common air, it acts like the common eudiometrical substances, and gradually absorbs oxygen.

This muriat, when heated *per se* in a retort, first gives out water and acid, which carry up a small quantity of tin, after which the remaining muriat quietly fuses in the retort, without further change, till the heat is raised to low redness; but it then sublimes almost entirely, and concretes in the neck of the retort in a solid form, leaving only a small quantity of a white oxyd behind, which becomes fixed, owing to a deficiency of acid.

The sublimed muriat does not appear to be changed by this process, except by the loss of part of its acid, for by the addition of a little fresh muriatic acid, it totally dissolves, and, as before, gives a black precipitate with corrosive muriat of mercury; so that it still remains in a low degree of oxygenation. On the other hand, the muriated *super-oxyd* is volatile at a very gentle heat, as we shall presently mention; so that distillation furnishes a ready method of separating these two muriats, the super-oxydated salt rising entirely at a much less degree of heat than that at which the sub-oxydated salt acquires any volatility.[i]

When the crystals of the muriated sub-oxyd are dissolved in a good deal of water, the solution soon becomes milky, and a considerable precipitate is formed.[k] This precipitate is soluble with ease in muriatic acid, and this solution gives, as at first, a black precipitate, with corrosive muriat of mercury, and with hydro-sulphuret of potash; consequently the degree of oxygenation is not altered. It also dissolves in nitric acid, and the solution deposits luna cornea with nitrat of silver, and consequently contains muriatic acid. By distillation, in open fire, it gives some vapour of muriat of tin, and afterwards muriatic acid, and a grey oxyd is left behind. This precipitate, therefore, is the muriat with excess of oxyd, or (what amounts to the same) the oxyd with deficiency of muriatic acid, and would be accurately termed a *sub-muriated sub-oxyd*; and, on the other hand, the supernatant liquor contains the metallic salt with an excess of acid, so as to redden litmus. Here, therefore, as in many similar instances, (such as that of the sulphat of mercury and turbith) the dilution of the salt with much water causes an unequal separation of its constituent parts, the insoluble portion containing much oxyd and little acid, and the soluble portion, the reverse. By adding muriatic acid, all the precipitate disappears, and the whole becomes an uniform solution, with excess of acid. In all these changes the degree of oxydation is not apparently changed.

The action of the alkalies and alkaline earths on the solution of muriated sub-oxyd of tin, is curious and complicated. If a few drops of caustic potash, for example, are added to this solution, a white precipitate takes place, which, however, is not a pure oxyd of tin, as might be

[i] Proust. [k] Berthollet Chemical Statics, (Note to vol. ii.)

ſuppoſed, but a *ſub-muriat*, preciſely the ſame as the ſalt produced by adding much water to the cryſtallized muriat. The ſupernatant liquor *is ſtill acidulous*, ſo that the firſt effect of the alkali is not to ſaturate the whole exceſs of acid, but to abſtract the greater part of the acid from that portion only of the muriat which is precipitated as a ſub-muriat. This action of the alkali continues to the laſt, ſo that as long as a particle of muriat of tin remains in ſolution, it remains acidulous. If the addition of potaſh is continued after all the metal is precipitated from the ſolution as a ſub-muriat, (no artificial heat being uſed) this precipitate gradually diſappears, and a triple combination of muriatic acid, potaſh, and ſub-oxyd of tin, is formed, which is partly cryſtallizable in rhomboidal priſms. The triple ſalt, produced in a ſimilar manner, by ammonia and by barytes, aſſumes the ſame form; when by ſoda or ſtrontian, the form is that of fine needles; the muriat of tin and lime is deliqueſcent. If, however, the precipitated ſub-muriat is digeſted with an alkali, and *heat applied*, the acid is totally ſeparated from the oxyd, and the latter is either re-diſſolved in the alkali, or, if but little alkali be uſed, moſt of it remains at the bottom in the form of a pure grey ſub-oxyd, in which the proportion of oxygen is only about 22 per cent. whereas the ſuper-oxyd formed by nitric acid and tin, and deprived of its ſmall retent of acid in the ſame way, contains about 28 per cent. of oxygen.

The carbonats of potaſh and ſoda precipitate the ſolution of muriat of tin with a briſk effervescence. The precipitate is not however a carbonat of tin, but a ſub-muriat, as with the pure alkalies, and an exceſs of the carbonat in the ſame manner, re-diſſolves the precipitate.

Another change, however, takes place, when the alkalies are digeſted with the oxyds of tin. The alkalies diſſolve both theſe oxyds, but their affinity with the ſuper-oxyd is much greater than with the ſub-oxyd; whence it happens, that if a clear ſolution of the ſub-oxyd in cauſtic potaſh be kept in a perfectly cloſed veſſel, at the end of ten or twelve days a ſingular cauliflower-ſhaped depoſit is formed, which Prouſt conſiders as reguline tin, but which appears rather to be tin in an extremely low ſtate of oxydation, as it is ſoluble in cold muriatic acid, without giving out hydrogen.[1] The ſupernatant alkaline liquor, on the other hand, now contains the metal in the higheſt ſtate of oxydation; for when ſeparated from the alkali by muriatic acid, and re-diſſolved in the ſame menſtruum, it gives no precipitate whatever to the ſolution of corroſive mercurial muriat, which is a teſt of the ſuper-oxydated ſolutions.

In this caſe an unequal diviſion both of the metal and oxygen takes place; one part of the metal, into which the greater part (if not all) of the oxygen is condenſed, forms a permanent union with the alkali, and the remainder of the metal falls down nearly in the reguline ſtate, and ſymmetrically arranged. This change takes place more ſpeedily, by boiling a ſolution of potaſh on a greater quantity of the oxyd precipitated from a muriat than it is capable of diſſolving.

We proceed to the Super-oxydated Muriat. This ſalt was long partially known, before its true nature was explained, as it conſtitutes, when concentrated by diſtillation, that ſingular ſmoking compound firſt diſcovered by Libavius, which on that account was termed *Smoking Liquor of Libavius*. It is prepared in the following way: melt, in an iron ladle, 5 oz. of pure tin, add to it 5 drams of mercury, ſtir them together, and pour out the amalgam into a marble mortar, into which put 20 oz. of corroſive mercurial muriat in fine powder, and mix the whole thoroughly. Put the whole of the mixture into a glaſs retort, with a receiver, not quite cloſely luted, and apply a moderate heat, with an Argand lamp or a ſand bath. At firſt, about 5 oz. of a colourleſs liquid diſtills over quietly, after which there riſes, quite ſuddenly and with a moderate exploſion, a great quantity of white heavy vapour, which condenſes into a tranſparent liquid, and mixes with that which has firſt paſſed. This is to be quickly poured into a well-ſtoppered glaſs phial, and is the *Smoking Muriat of Tin*, or *Liquor of Libavius*. The uſe of the mercury, in amalgamating the tin, is merely for the convenience of dividing it, as the filings of tin alone, with the corroſive muriat, will anſwer the ſame purpoſe.

Prouſt gives, as the beſt proportions, 8 oz. of *powder* of tin, (probably ſuch as is made by melting the metal, and ſhaking it in a box) and 24 oz. of corroſive ſublimate, which affords 9 oz. of the ſmoking liquor.

If the receiver be changed after the ſmoking liquor has come over, and the heat be very much increaſed, a ſolid *butter of tin* firſt ſublimes, which appears to be the muriated ſub-oxyd, mixed with globules of mercury, when the amalgam has been originally employed. Together with this muriat there riſes a quantity

[1] Berthollet.

of calomel arising from the partial decomposition of the corrosive muriat, and if the heat has been kept at redness for a sufficient time, all the muriated sub-oxyd of tin, calomel, and running mercury, will be sublimed, and only a grey powder left, which is probably chiefly a sub-oxyd of tin.

The smoking muriat when inclosed in a bottle presents nothing remarkable, but the empty part of the bottle above the level of the liquid soon becomes lined with crystalline needles, which generally cause the stopper to adhere to a very troublesome degree. When this liquor is exposed to the air it immediately sends forth a quantity of dense white vapours which excite coughing, and condense into a semi-crystallized pellicle on the contiguous surfaces. The precise nature of this singular liquid has been illustrated by a very ingenious series of experiments by M. Adet,[m] and afterwards by M. Pelletier.[n]

From those of the former chemist we have the following facts: when a little of this liquor is poured into a cup, and enclosed under a bell-glass *over water*, the whole of it evaporates in white fumes, which presently crystallize on the sides of the glass in the form of a saline vegetation. These crystals have now lost the property of smoking, are somewhat deliquescent, and readily dissolve in water into an acid solution of muriat of tin. This crystallized condensation of the vapour is owing to its union with the moisture held in solution in the air, and which is constantly supplied by the water over which the vessel stands, so that in fact this substance is a most powerful hygrometer. In proof of which M. Adet found, that when the fuming muriat was confined with a small quantity of *dry air*, scarcely any of the crystalline vegetation was deposited, but it immediately appeared when the air from the lungs was introduced, which is known to be loaded with moisture. The smoking muriat therefore loses its smoking property, and solidifies by union with a certain quantity of water, and is again reducible to a liquid by a greater proportion of water. This may also be shewn more directly; when the muriat is mixed with not more than about a third of its weight of water, much heat is given out, and the whole suddenly congeals, at a common temperature. At the same time a number of bubbles of gas, apparently pretty pure azot, are given out, the cause of which is not very obvious, but it seems to bear an analogy with the expulsion of air from water, and all other liquids in the act of freezing; and both in this circumstance, as well as in the evolution of caloric, the fixation of the water may be considered as equivalent to congelation. This solid mass readily liquefies in a gentle warmth, and by the addition of more water it is resolved into a mere solution of the superoxydated muriat of tin without giving out any more vapours.

The habitudes of this muriat with reguline tin throw much light upon its true nature. If this muriat, diluted with so much water as to become solid when cold, is liquefied by heat and digested with some filings of tin, a considerable portion of the fresh metal is dissolved, *without the disengagement of hydrogen* or any gas whatever, and when saturated, the solution has now lost all the characteristic properties of the smoking muriat, will bear being heated to redness with very little loss by sublimation, and then concretes into a brown mass which closely resembles the common fused *muriated sub-oxyd*. This striking experiment shews, in the first place, that the tin in the smoking muriat is in a high state of oxydation, so that it can impart a portion of oxygen to an additional quantity of metal sufficient for its solution; for as no hydrogen is given out, the oxygenation of the fresh portion of metal cannot (as in the common solution in the muriatic acid) arise from the decomposition of water. It also shews that tin in a low state of oxydation requires much less muriatic acid for its solution than in the higher state, (and consequently that its affinity for the acid is stronger) otherwise the tin last added, though oxydated, could not be held in solution, as it is, and with that sensible excess of acid which, as we have already mentioned, is essential to a solution of the muriated sub-oxyd.

Pelletier in his experiments on muriat of tin (many of which have been already related) endeavoured to form the smoking muriat by compleatly oxygenating the common solution of tin in muriatic acid. This he effected by passing oxymuriatic gas through this solution, which absorbs it readily, 2400 grs. of tin dissolved in four times its weight of common muriatic acid taking up 2 oz. of the gas. This liquid, boiled for a few minutes to expel a little uncombined gas which it contained, yielded a clear limpid solution, free from the peculiar pungent smell of oxymuriatic acid, in which the metal is certainly as highly oxygenated as possible. When this solution was evaporated considerably it deposited crystals exactly resembling those afforded by the smoking muriat when a little

[m] An. Chim. tom. 1.

[n] Memoires de Pelletier, tom. 1.

diluted with water, and by further evaporation a solid salt was obtained, which, like the smoking muriat sublimed totally in a moderate heat. It does not appear whether this accurate chemist made any further trials to ascertain the identity of the two solutions, but they appear to resemble each other in every property, but that of fuming, which could not be given to the solution prepared by oxymuriatic acid gas. It is probable, however, that this property only depends on the extreme concentration of the muriat prepared by distilling tin and *dry* corrosive muriat of mercury, for M. Adet also found, that on adding water to these materials before distillation, the distilled liquor was not fuming, but resembled the fuming muriat after dilution.

This muriat gives no precipitate with the solution of gold, but only changes the colour to a clear claret red. It is decomposed by the alkalies, partially when cold and entirely when heated; but the oxyd of this salt is more readily soluble in an excess of alkali than the sub-oxyd of the other muriat.

It may be useful to recapitulate in a few words the characteristic properties of the two muriats.

The *sub-oxydated muriat* is made simply by dissolving tin in muriatic acid; it gives no fumes on exposure to air—gives a black precipitate with hydrosulphuret of potash—has a very strong affinity for oxygen, and in consequence gives a black precipitate with corrosive sublimate, which is converted by heat into running mercury; gives a red purple precipitate with nitro-muriat of gold, and diminishes the state of oxydation of all other metallic solutions—absorbs oxygen from the air, and oxymuriatic acid gas when passed through it, and destroys the peculiar smell of the latter substance—is crystallizable—requires a low red heat for its sublimation.

The *super-oxydated muriat* is made either by dissolving the perfect oxyd in muriatic acid, or by saturating the former muriat with oxymuriatic gas, or by distilling dry corrosive sublimate of mercury and tin, in which last case it is volatile in the atmosphere in dense fumes, which crystallize by absorbing moisture; it gives a yellow precipitate with hydrosulphuret of potash, and no precipitate at all with nitro-muriat of gold, or with a solution of corrosive muriat of mercury—it dissolves a fresh quantity of metallic tin without the production of hydrogen, and then is changed to the sub-oxydated salt—it has no further affinity for oxygen (being saturated with this principle)—and it is totally volatilized in distillation at a very gentle heat.

Muriatic acid appears to have a stronger affinity for the sub-oxyd of tin than for the super-oxyd, for the solution of the latter oxyd gradually deposits a quantity of its oxyd by keeping, which the solution of the former does not readily do unless much diluted with water, or unless it is kept in a bottle loosely stopped, which allows it to absorb oxygen from the air.

On the other hand, the alkalies have much the strongest affinity for the most highly oxydated tin.

The nitro-muriatic acid dissolves tin copiously and with great ease, and is the acid commonly employed for the solution of this metal in the large way for the use of the dyers, with cochineal colours. A mixture of two or three parts of muriatic acid and one of nitric, forms the best proportions for this compound acid. A violent effervescence is excited when the tin is immersed, and much heat is generated, which if too great, would cause most of the metal to separate in the form of a white insoluble oxyd, so that the vehemence of action should be checked by setting the vessel in cold water, and adding the tin by very small portions at a time. In this way the concentrated nitro-muriatic acid will hold in solution about half its weight of tin, but if the acid is not previously a good deal diluted, it congeals, when cold and saturated with metal, into a tremulous gelatinous mass, generally somewhat opalescent and semi-opake, which by keeping, hardens considerably. The addition of a small quantity of water only increases its solidity, but a greater quantity restores its liquidity, with the deposition however of a part of its metallic contents, as an insoluble oxyd. When this solution is heated a new effervescence is excited, and if not too dilute, it hardens into a transparent gelly on cooling.

The solution actually made by the scarlet dyers,* and called by them *Spirit*, is prepared with that species of dilute nitric acid, termed *single aqua fortis*, to every pound of which are added from one to two ounces of common salt or sal-ammoniac. The acid thus prepared will dissolve about an eighth of its weight of tin, which is previously granulated by being poured, when melted, into water briskly agitated by rods. This acid is still further diluted, and the heat of solution is checked by setting it in cold water, and adding the metal very gradually. The process of solution is thus protracted to two or three days.

* Bancroft on Colours.

The state of oxydation of the metal in this solution must vary, but when it is recent, and has been made very gradually, and without heat, the tin must be in low oxydation, which is the state probably the most desirable for the dyer, as the acid is more saturated and less liable to deposit oxyd by keeping.

When tin filings are thrown into oxymuriatic gas they take fire and burn with a bluish-white flame. The residue is partly soluble in water.

The liquid oxymuriatic acid dissolves this metal quietly without effervescence. The result is a muriat of tin more or less oxydated according to the quantity of acid employed.

Most of the vegetable acids act upon tin.

Vinegar, either common or distilled, when digested with tin filings, particularly with the assistance of heat, assumes a whitish opalescent colour, a disagreeable smell and metallic taste, gives a yellowish white precipitate with hydrosulphuret of potash, and a deep purple precipitate with nitro-muriat of gold. It therefore holds the tin which it has dissolved, in a low state of oxydation. This solution readily deposits most of its metallic contents as an insoluble oxyd, when by exposure to air it has absorbed an additional quantity of oxygen. If the recent solution is slowly evaporated till it begins to shew a saline crust, and is then suffered to remain undisturbed in a cool place for a day or two, it deposits groups of needle-formed crystals of acetite of tin.

The acetic acid, being more concentrated than common vinegar, dissolves tin more readily and in somewhat larger quantity, but even with this acid the quantity dissolved is very small.

The sub-oxyd of tin produced by saturating the common muriat by a carbonated alkali, also dissolves in vinegar, but the perfect oxyd is insoluble in this as in most other acids.

Carbonated water added to a solution of acetited tin causes a white powder to precipitate, which is probably a carbonated sub-oxyd.

A very concentrated acetite of tin is made [p] by adding a saturated solution of crystallized muriat of tin to acetited lead. A double decomposition takes place, muriat of lead is precipitated, and the supernatant liquor is chiefly a strong acetite of tin. This is strongly recommended by the inventor as a mordant for a variety of dyeing processes.

Tin is soluble in the acid of tartar, and this solution is of importance in manufacture, as it is the method by which *wet tinning* is performed on copper and brass. Pins are whitened in this manner, but by a compound menstruum.

This process is easily performed: a solution of about one part of cream of tartar, two parts of alum, and as much common salt, is made in a moderate quantity of water, and tin filings or granulated tin is thrown in, and the liquor boiled. The pins, which are made of brass wire and perfectly bright, are then put in, and after remaining in the boiling liquor for a time, they are compleatly covered with a beautiful white uniform coating of tin, which is the state in which they are used.

It is not necessary to employ this mixture of salts for the mere tinning of copper or brass. Either of these three salts singly with tin filings will answer the purpose, but cream of tartar gives a duller and more leaden-looking tinning, and alum on the other hand gives a very fine silver white but without gloss, so that the mixture above-mentioned is found to produce the most desirable hue.

In a chemical point of view this operation is curious, and appears to present a contradiction to the usual laws of affinity, for when tin is immersed in a common solution of copper, it precipitates most of the copper in the metallic state.

The circumstances requisite to produce a precipitate of metallic tin on copper, have been examined in an able set of experiments by Prof. Gadolin, a Swedish chemist, an account of which is inserted in the Stockholm Transactions for 1788, to which are added some other experiments and remarks by Baron de Gedda.[q] It is to be observed, that the circumstances relating to the oxygenation of metals in their solutions in acids were very incompleatly known at that time, so that we may now account for phenomena which must have been inexplicable at that period. The facts however cannot vary, and are always valuable. This chemist chiefly confined himself to the action of a single salt, namely tartar, or its acid. We shall select and give in a few words some of the experiments.

1. Tartrite of potash was added to nitro-muriat of tin, which caused a white precipitate of tartrite of tin, which was edulcorated and dried. Some of this precipitate was boiled with water, and copper was immersed, but the copper was in no degree altered.

2. Some of the above tartrite of tin was acidulated with tartareous acid and copper was boiled in it, but with no effect.

3. Some of the same tartrite of tin was treated

[p] Haussman.

[q] Journ. de Phys. tom. 34, p. 362 & 430.

treated as in the laſt experiment, but with the addition of ſome leaf-tin and the copper was now compleatly tinned.

4. The laſt experiment was repeated, but without an exceſs of acid, and no effect was produced on the copper.

5. Cream of tartar, tin filings, and a piece of copper, were boiled together, and the copper was compleatly tinned.

Theſe experiments ſhew that in order to precipitate tin upon copper by means of tartar, it is neceſſary, both that ſome metallic tin ſhould be preſent in the ſolution, and that the ſolution ſhould contain an exceſs of acid.

6. Some oxyd of copper ariſing from the decompoſition of blue vitriol by an alkali, was firſt boiled in a ſolution of cream of tartar, after which both tin-leaf and copper were introduced, and the whole boiled together for three hours. Both the copper and tin were covered with a cruſt of blackiſh metallic alloy.

7. Some copper was tinned by boiling with tin and a ſolution of tartar. The liquor after the copper was withdrawn was not changed to blue by volatile alkali, and hence was inferred to contain no copper, though when expoſed to the light ſome faint blue ſtreaks were obſervable.

8. The ſame experiment was repeated with tartar, alum, and ſalt, (the uſual mode of tinning) and no indications of copper were furniſhed by the volatile alkali.

9. Copper was tinned with each of the above three ſalts ſingly, and in neither inſtance did the volatile alkali give any indications of diſſolved copper in the liquor.

10. Tin-leaf was boiled for an hour with a ſolution of cream of tartar. The tin was then withdrawn and a bar of iron introduced, and the boiling continued. The iron was ſoon blackened at its ſurface, and after three quarters of an hour, was covered with a mixture of reduced metallic tin and oxyd of tin, and the iron had loſt weight in the proceſs.

Hence as iron was found to precipitate tin in a metallic ſtate from its ſolution, it was conjectured that iron added to a ſolution of tin, in which copper was immerſed, might determine the tinning of the copper. The experiment however ſucceeded but imperfectly when tartar was uſed, owing to the languor of its action on iron, and even when a few drops of ſulphuric acid were added, the tin was precipitated ſolely on the iron, whilſt the ſurface of the copper remained unaltered, but with alum it was different.

11. Some tin-leaf was boiled with a ſolution of alum for half an hour and then withdrawn. Into the ſolution were then introduced a piece of poliſhed copper, and ſome iron filings. The latter were acted on with much rapidity, and in a few minutes the copper was covered with a pellicle of tin, which in half an hour gave it the appearance of fine ſilver unpoliſhed.

12. Tin-leaf and a ſolution of alum were boiled together. The tin was then taken out, and into the ſolution both iron and copper were introduced, each poliſhed. After a few minutes boiling both theſe metals were highly tinned.

13. Some ſulphat of copper was diſſolved in water, tin leaf was added, and the mixture was expoſed to a moderate heat for ſome days in a well cloſed phial. In a few days the colour of the ſolution entirely diſappeared, and the copper precipitated to the bottom of the veſſel. The clear ſupernatant fluid was diſtributed into three phials, into the firſt of which was put copper and tin; into the ſecond, copper and iron; and into the third, copper alone. They were well corked, and after digeſtion in moderate heat for ſome hours the copper in the firſt phial, and the copper and iron in the ſecond were well tinned, but the copper in the third remained unaltered.

From the above experiments we may clearly make out that the ſtate of the ſolution of tin, when it is diſpoſed to precipitate in a metallic form on the ſurface of copper immerſed in it, is that of the loweſt degree of oxydation, which is obtained either by keeping ſome undiſſolved tin in the ſolution or (Exp. 10 and 11) by introducing iron. The great difficulty which occurred to the author of theſe experiments was to account for the precipitation of the tin when there did not appear to be any copper diſſolved during the proceſs, for in all other metallic precipitations (as that of copper on iron for example) the ſeparation of one metal from the ſolution is attended with the ſolution of a correſponding quantity of the other metal.

The difficulty is increaſed too by the fact that when tin is immerſed in a ſolution of copper the copper is precipitated, and a portion of the tin is diſſolved, ſo that the direct affinity of acids for tin is greater than for copper.

The hypotheſis given by Prof. Gadolin to explain this is highly ingenious. He obſerves that as a very ſtrong affinity exiſts between tin and copper, this affinity operates on the metallic part of the ſolution of the tin immediately in contact with the copper, and cauſes its ſepa-

ration in the metallic form, whilſt the remainder of the tin, which is the greateſt portion, undergoes a greater degree of calcination (i. e. oxygenation) and hence too the ſolution after its utmoſt action on copper ſtill retains a quantity of tin. In other words, the diſſolved tin divides itſelf into two portions, one of which returns to the metallic ſtate, and adheres to the copper, whilſt the whole of the oxygen condenſes in the other portion, which remains diſſolved.

To ſhew that a correſponding ſolution of the *precipitant* (i e. the copper) is not neceſſary to the ſeparation of the *precipitate*, M. Gadolin boiled ſome fine gold with tin and tartar, and after a ſhort time the gold was compleatly covered with a coating of reduced tin, and it cannot be ſuppoſed that any of the gold ſhould have been diſſolved by the tartar. This experiment would have been more compleat if the tin had been again ſeparated from the gold by muriatic acid, and the gold had been weighed beſore and after the operation, but if this ſtatement is accurate (which there is no apparent reaſon to doubt) it is a curious fact, and one for which in addition to M. Gadolin's explanation, we muſt probably refer to the late diſcovered experiments in Galvaniſm. This is confirmed by the circumſtance that in every one of the experiments on tinning above related, the preſence of two diſſimilar metals in the reguline ſtate is required, ſo that the moment the metallic tin is withdrawn from the tartareous ſolution the precipitation of tin upon copper ceaſes, though we can hardly ſuppoſe that any immediate change in the ſtate of oxygenation of the ſolution takes place.

With reſpect to the circumſtance of no copper being found in the ſolution of tartar after common tinning, we may obſerve however that the failure of the uſual teſt of the volatile alkali is no certain proof of the abſence of this metal in this inſtance, as the later diſcoveries of Prouſt on this ſubject (which are detailed under the article *Copper*) ſhew that when copper is in ſolution with tin in a low ſtate of oxydation, it is ſo far deprived of oxygen by the tin, as not to turn blue with ammonia.

The experiments in which iron, copper, and tin were immerſed into a ſolution of tin, are complicated, and the exact operation of all the affinities between the reſpective ſubſtances is not eaſily made out. The order of precipitation with a ſingle metal, and a ſingle metallic ſolution, is copper, tin, iron; that is to ſay, iron immerſed into a ſolution of tin diſplaces the tin, and precipitates it moſtly in the metallic form; and tin immerſed into a ſolution of copper precipitates the latter metal. But in the above complicated caſe both the iron and copper become tinned, ſo that the tinning of the iron may be effected by ſimple and direct affinity, but that of the copper requires a complicated action, to which probably the metallic tin preſent contributes.

When cream of tartar has been long boiled with tin till it can diſſolve no more, the ſolution ſtill remains acidulous, and when evaporated and cryſtallized a triple ſalt is obtained, compoſed of tartareous acid, potaſh, and oxyd of tin, which may be termed a *ſuper-tartrite of potaſh with tin*.

The fixed alkalies have ſome action upon metallic tin, tarniſhing its ſurface and diſſolving a ſmall portion though with difficulty. But on the oxyds of this metal alkali acts with great energy, diſſolving them copiouſly and with eaſe. The circumſtances of ſolution and precipitation of the oxyd from the acid ſalts by potaſh, have been already mentioned. Potaſh appears to have a ſtronger affinity for the perfect oxyd than the ſub-oxyd, ſo that in a mixture of the two it diſſolves the former in preference. This ſolution does not readily depoſit its oxyd by keeping, or by expoſure to air, as the ſolutions of the ſame oxyd in acids do, but may be cryſtallized by gradual evaporation.

The effect of alkalies in breaking the aggregation of the native oxyd, and thus rendering it ſoluble in acids, has been mentioned in the analyſis of the ores.

Muriat of ammonia acts upon tin by the aſſiſtance of heat. When this ſalt and tin filings are heated in a retort, a ſmall quantity of hydrogen gas is firſt given out,[*] and if the heat be continued, for a time, below redneſs, a ſaline maſs is formed, compoſed of muriated ammonia, muriat of tin, and ſome tin filings unchanged. The muriat of tin contains the metal in the ſtate of ſub-oxyd, as it gives a purple precipitate with ſolution of gold, and a black one with hydro-ſulphuretted water.

Tin unites readily with ſulphur by fuſion. For this purpoſe melt ſome tin in a crucible, heat it ſhort of redneſs, throw upon it about a third or a fourth of its weight of ſulphur, and ſtir them together when melted. The mixture inflames when heated to a certain degree, and ſhould then be covered. When this has ſubſided remove the crucible, and black brittle ſul-

[*] Prouſt.

phuret of tin is obtained. To saturate the tin with sulphur the heat should be moderate, and the projection of sulphur repeated once or twice, till the tin appears to be saturated.

The quantity of sulphur retained by the tin in this process is variously given, and no doubt actually varies. Mr. Woulfe[s] found 4 oz. of tin to furnish 5 oz. of the sulphuret, and even then it is not entirely saturated, for on rubbing it in a mortar a portion remains which extends under the pestle, and therefore is still malleable and unsaturated with sulphur.

On the other hand, Bergman finds that 100 parts of tin will take up in this way no more than 20 of sulphur, in which proportions Proust agrees. But Pelletier[t] found the increase on 100 of tin to be no more than 16½ of sulphur, so that the saturating proportions of sulphur and tin are still unknown, and could only be determined with accuracy by adding an excess of sulphur to the pulverized sulphuret made in the way above mentioned, and keeping the mass just at fusion in a close retort as long as any sulphur sublimed from it.

This sulphuret is a black brittle shining substance, of a flaky consistence, and closely resembling molybdena in appearance. When melted and cooled very slowly it assumes a lamellar texture, in the hollows of which are seen distinct needled and sometimes cubic crystals.

This sulphuret is not acted on by a solution of caustic potash.[u] When digested with nitric acid a large quantity of nitrous gas is given out, from which, and from the analogy with the other sulphurets made by fusion, we may conclude the metal to be in the reguline state in this compound.

When a current of sulphuretted hydrogen-gas is passed through any solution of super-oxydated tin,[v] a yellow precipitate of *hydro-sulphuretted super oxyd* gradually collects, which takes place with more ease if a little alkali is previously added to the solution till the moment that a precipitate begins to appear. When the hydro-sulphuret is *heated* with muriatic acid it again quits the oxyd of tin with effervescence, and resigns it to this acid. Hence it appears that the affinity of sulphuretted hydrogen for this oxyd of tin is greater than that of muriatic acid in a low temperature, but less, when the heat is raised. When this yellow hydro-sulphuret is dried it becomes vitreous in its fracture, it is easily soluble in potash, and precipitated thence by acids unaltered. When gradually heated *per se*, water, sulphureous acid, and some sulphur are given out, and the residue, if not overheated, is the golden sulphuretted oxyd of tin, or *Aurum Musivum*, which will be presently described at large. The affinities that act in this process are complicated. They are stated by Proust to be the following: the oxyd of tin gives out part of its oxygen, of which one portion unites to the hydrogen of the hydro-sulphuret, and forms water, and the remainder carries off with it part of the sulphur as sulphureous acid; some excess of sulphur beyond the requisite proportions for the aurum musivum is also volatized; whilst the remainder of the sulphur, and the tin, now in low oxydation, unite into the aurum musivum which remains behind.

When sulphuretted hydrogen gas is passed through a solution of sub-oxydated tin, such as the common muriat recently made, a dark coffee-coloured precipitate takes place, which is the *hydro-sulphuretted sub-oxyd*, and when washed with boiling water it dries of the same colour.

This hydro-sulphuret is also decomposed by muriatic acid with effervescence in a boiling heat, but it gives no aurum musivum when heated *per se*. When heated with a solution of caustic potash, both a solution and precipitation take place; the precipitate is the simple sulphuret with the tin in the metallic state; the solution on the other hand, is a hydro-sulphuret of potash holding the metal in the highest state of oxydation, since acids precipitate the hydro-sulphuret yellow, like that first described. The potash therefore causes the condensation of all the oxygen into a portion of the substance, together with all the hydrogen, at the expence of the other portion, which is then found destitute of both. This effect of potash, in concentrating all the oxygen into that portion which it dissolves, is analogous to what occurs in other cases, and depends on the much greater affinity of the super-oxyd than of the sub-oxyd for this alkali. A similar action takes place when the sub-oxyd of tin, sulphur and solution of potash are heated together, and a hydro-sulphuret of super-oxydated tin is produced. In like manner if liquid muriated sub-oxyd of tin is poured into liquid sulphuret of potash, a yellow precipitate takes place, which is the super-oxydated hydro-sulphuret.

A beautiful golden-coloured species of sulphuret of tin has long been known in the arts, under the name of *Aurum Musivum*, or *Mosaicum*, (*Mosaic Gold*). It is in the form of a

[s] Phil. Trans. vol. 61. [t] Memoires, vol. 2. [u] Proust Phys. tom 61. [v] Ibid.

scaly mass, sometimes crystallized in six-sided plates, very soft and glossy to the touch, readily rubbed down between the fingers, and when the colour is brought out by a little friction, having a fine golden metallic lustre. It is still prepared in pretty large quantities by some artists, and is supposed to be used principally in artificial bronzing and other ornamental purposes. It was formerly employed in medicine. A great number of receipts have been given for preparing it, most of which succeed nearly equally well, provided the same attention to management of the heat, &c. be observed. It is also interesting to experimental chemistry, and its properties have been examined by several excellent chemists, among whom may be enumerated Mr. Woulfe,[x] the Marquis de Bullion,[y] and M. Pelletier.[z]

The old process for aurum musivum, and which is one of the best, is the following; as contained in the London Dispensatory.[a]

Take 12 oz. of tin, 7 oz. of flowers of sulphur; sal-ammoniac and quicksilver, of each 6 oz. melt the tin by itself, add to it the quicksilver, and when the amalgam is cold reduce it to powder, and mix it with the sulphur and sal-ammoniac, and sublime the whole in a glass matrass, standing in a sand-bath. Apply a gentle fire for some time, till the white fumes which arise copiously at first, begin to abate, then raise the fire till the sand becomes red-hot, and keep it at this point, neither increasing nor diminishing it, for a considerable time, according to the quantity of the materials, till you judge the operation to be compleated. The matrass being broken when cold, the mosaic gold is found at the bottom, and above it a sublimed substance, the composition of which will be presently mentioned.

The mosaic gold therefore is not a *sublimate*, but is a fixed substance, and it cannot be raised by heat unchanged. It weighs considerably more than the tin employed, but the actual product is extremely uncertain. A good deal of care is required in managing the fire, for if too slack none of the mosaic gold will be formed, and if urged beyond a moderate redness it is again decomposed into a dark sulphuret of tin, totally without lustre. The proportions of the ingredients are variously given. Formerly equal parts of all the substances were employed, but they may be reduced to the proportions here given without diminishing the product.

As soon as the ingredients are mixed an odour of sulphuretted hydrogen is given out, which increases rapidly as heat is applied; and if the process be performed in a retort, with a receiver attached to it, a quantity of hydro-sulphuret of ammonia or volatile liver of sulphur, comes over, which condenses in the extremity of the receiver, partly as a liquid and partly in beautiful crystalline needles. The sublimate which is formed above the aurum musivum, and which is much less volatile than the ammoniacal hydro-sulphuret, is an extremely compound substance, (in the usual way of preparing it) consisting chiefly of cinnabar, of muriated ammonia, and some muriat of tin, from which by a fresh sublimation an additional quantity of the aurum musivum may be obtained. This latter appears to be contained in the first sublimate, and indeed may often be found interspersed in it in shining hexagonal plates, but as aurum musivum alone cannot be sublimed, this portion is supposed to be formed by the muriat of tin and sulphur combining in the act of volatilization.

The decompositions and changes that take place in the preparation of aurum musivum with mercury, tin, muriat of ammonia, and sulphur, are numerous and somewhat complicated. The principal ones appear to be the following: the mercury at first seems nearly passive in the operation, and serves merely to divide the tin, and render it easily reducible to powder, but when the heat is increased the mercury volatilizes and unites with the sulphur into cinnabar. The tin is certainly first acted on by the sal-ammoniac decomposing the water which it contains, the oxygen of which it absorbs, and the oxyd of tin thus produced is immediately dissolved by the muriatic acid of the sal-ammoniac forming a muriat of tin. This process sets at liberty two very volatile substances, viz. the hydrogen of the water decomposed, and the ammonia of the salt, both of which, in volatilizing carry up a sufficient quantity of the sulphur present to constitute the hydro-sulphuret of ammonia, which flies off in white fumes in the common way of proceeding, or, as already mentioned, may be collected in a receiver joined to the apparatus.

The ingredients in the matrass are now changed, more or less compleatly, to muriat of tin, mercury, and sulphur; and as the heat is increased all the mercury and part of the sulphur sublime, and unite into cinnabar; the muriat of tin is decomposed by another part of

[x] Phil. Trans. vol. 61. [y] Journ. de Phys. tom. 20. [z] Memoires de Pelletier. [a] New Dispensatory for 1765.

the ſulphur, the muriatic acid is volatilized, taking with it a portion of the tin, and finally the remaining oxyd of tin and the reſt of the ſulphur, unite to form the aurum muſivum that remains at the bottom of the veſſel.

It is to be obſerved that the ſole uſe of the mercury in this mixture is to enable the tin to be reduced to powder, ſo that the mixture may be ſimplified by omitting the mercury, provided the tin is reduced to powder, or otherwiſe divided. The ammonia of the ſal-ammoniac is alſo entirely ſuperfluous, and even the ſole uſe of the muriatic acid is to enable the tin to oxydate itſelf by the decompoſition of water, which it effects by the reſulting affinity of oxyd of tin for muriatic acid. So that in fact the only neceſſary ingredients for aurum muſivum appear to be oxyd of tin and ſulphur, the latter in conſiderably larger proportion than it exiſts in the black ſulphuret.

Theſe obſervations will be explained and illuſtrated by a ſhort abſtract of a variety of other proceſſes given by different chemiſts, by which aurum muſivum may be made.

The three following are given by Mr. Woulfe.

1. Take 10 oz. of black ſulphuret of tin, (formed by ſaturating melted tin with ſulphur) mix it with 4 oz. of ſulphur and 2 oz. of muriatic acid, calcine the mixture, and heat the reſidue in a matraſs in the uſual way. This gives a tolerably good aurum muſivum.

2. Take 4 oz. of tin, ſaturate it with ſulphur, powder it well, and mix it with 2 oz. of ſulphur and 1 oz. of cryſtallized muriat of tin. Calcine and heat as in the laſt proceſs. This gives $6\frac{1}{2}$ oz. of a very fine aurum muſivum.

3. Mix 10 oz. of black ſulphuret of tin with 16 oz. of corroſive mercurial muriat, put it into a retort with a receiver adapted to it, and apply a heat for ſix hours, at firſt with a moderate fire, and for the laſt three hours the retort muſt be red-hot.

In this proceſs the mercurial muriat is decompoſed, a portion of the tin riſes highly oxydated, and united to the muriatic acid in the form of the ſmoking muriat; another portion remains behind, united with part of the ſulphur into very beautiful aurum muſivum, whilſt the oxyd of mercury unites with another part of the ſulphur into cinnabar.

The ſame experiment repeated by Pelletier, with equal parts of the two ingredients, gave the fuming muriat of tin, running mercury, and aurum muſivum.

Brugnatelli [b] gives the following receipt:

4. Precipitate a ſolution of nitrat of tin by liquid ſulphuret of potaſh; dry the precipitate, mix it with half its weight of ſulphur, and a quarter of ſal-ammoniac, and heat as uſual.

The following are ſome of the intereſting experiments of Pelletier on this ſubject.

5. A ſolution of 600 grs. of tin was made in muriatic acid; to this were added 600 grs. of ſulphur, and the whole was evaporated to dryneſs. It was then reduced to powder and heated in the uſual way, and gave a ſublimate of muriat of tin, mixed with a little ſulphur, and the reſidue at the bottom of the veſſel was very good aurum muſivum.

6. Equal parts of tin filings, ſulphur, and ſal-ammoniac, were duly heated: the volatile products were hydro-ſulphuret of ammonia, ſulphuretted hydrogen gas, ſulphur, and ſome ſal-ammoniac, and very fine aurum muſivum remained.

7. Equal parts of black ſulphuret of tin and muriat of ammonia were mixed and heated. The reſidue was a black, irideſcent, friable, puffy maſs, very different from the ſimple ſulphuret, and appeared to be oxyd of tin, not ſaturated with ſulphur; and in this latter circumſtance therefore differing from aurum muſivum. This was confirmed by the following.

8. Equal parts of the black ſulphuret of tin, of ſal-ammoniac, and of ſulphur, were heated as above, and a good quantity of fine aurum muſivum was obtained. As there was more ſulphur than neceſſary, ſome ſulphuret of ammonia was ſublimed.

9. Equal parts of cinnabar and black ſulphuret of tin heated together, gave running mercury and aurum muſivum. Cinnabar conſiſts of ſulphur and oxyd of mercury, ſo that the ſulphuret of tin in this experiment deprived the cinnabar both of its oxygen and its ſulphur.

10. Equal parts of tin putty (*ſub-oxyd of tin*) and ſulphur gave, after much of the exceſs of ſulphur had ſublimed off, a black brittle maſs, viſibly penetrated with ſulphur, but no aurum muſivum.

11. Some tin putty was calcined with nitre, and thus converted into a white oxyd. Of this, 600 grs. were heated with 400 of ſulphur, and the products were, ſulphur and ſulphureous gas, and aurum muſivum.

12. The oxyd of tin, precipitated from the muriat by ſoda, and mixed with ſulphur, gave the ſame products as the laſt.

13. The oxyd of tin by nitric acid, mixed

[b] An. Chim. tom 29.

with two-thirds of its weight of ſulphur, gave the ſame products as the laſt.

In examining theſe experiments it appears that aurum muſivum may be made ſimply by heating ſulphur and oxyd of tin, but the three laſt experiments ſhew that it is neceſſary for the tin to be in a ſtate of high oxygenation.

Nevertheleſs, as in theſe ſimple proceſſes ſome of the ſulphur is converted into ſulphureous acid, for the oxygen of which no other ſource but the oxyd of tin appears, it may be doubted whether the tin remains in the higheſt ſtate of oxygenation in the aurum muſivum, though there can be no doubt that it is oxydated to a certain degree.

We may therefore conſider this ſubſtance as a ſulphuretted oxyd of tin, in which the oxyd is ſaturated with as much ſulphur as it can retain at a low red heat.

Aurum muſivum may be made as well, and much more economically, in a crucible as in glaſs veſſels. To make 10 or 12lb. of it requires about eight hours; but for an ounce or two in ſmall experiments about an hour will ſuffice.

Aurum muſivum, when well prepared, is without taſte, and entirely inſoluble in water. The acids have no effect on it. When muriatic acid is boiled with it, ſome ſulphuretted hydrogen is generally given out and a little tin diſſolved, but this is owing to the admixture of a portion of ſulphuret of tin, for if the reſidue is waſhed, no ſubſequent treatment with this acid produces any effect. It is in this reſiſtance to the action of muriatic acid, that aurum muſivum is particularly diſtinguiſhed from the ſimple ſulphuret and the more and leſs oxydated hydro-ſulphurets of tin.

When aurum muſivum is digeſted with a ſolution of potaſh and heated, it quietly diſſolves and forms a green liquid, from which acids ſeparate a yellow powder, which is the ſuperoxydated hydro-ſulphuret, and not regenerated aurum muſivum.

If moſaic gold is heated ſtrongly in a cloſe veſſel, (that is, to as full a red heat as a glaſs retort will bear) it is entirely altered in its nature, a large quantity of ſulphureous acid gas is given out, ſome ſulphur ſublimes, and the reſidue, which is nearly five-ſixths of the whole, is a black brilliant metallic-looking maſs, which appears to be chiefly ſulphuret of tin. A ſtrong heat therefore cauſes the union of part, if not all, of the oxygen of the aurum muſivum, with that portion of the ſulphur which flies off as ſulphurous acid.

Phoſphorus unites with tin with great eaſe, either directly by projecting phoſphorus on melted tin, or by heating vitreous phoſphoric acid or phoſphat of ammonia with tin, with or without the addition of charcoal.[c] In the former method a white regulus is obtained, cryſtallized externally, weighing from 12 to 15 per cent. more than the tin. When this phoſphuret is diſtilled with corroſive mercurial muriat, the products are ſmoking muriat of tin, running mercury, and phoſphuretted hydrogen gas, and in the retort there remains a tumid maſs, compoſed of phoſphorus and oxyd of tin. When equal parts of vitreous phoſphoric acid and tin filings are heated together, after the mixture has been a little time in fuſion, flaſhes of inflamed phoſphorus break up from the ſurface, and if it is immediately afterwards removed, two diſtinct ſubſtances are found in the crucible, the loweſt of which is phoſphuret of tin, which is ſoft enough to be cut by the knife; when hammered it extends, but ſplits into laminæ; has a ſilvery luſtre in the recently divided ſurface, and burns before the blowpipe with a phoſphoric flame, and a globule of pure tin is left, covered by a tranſparent glaſs. Above the phoſphuret of tin is a black glaſs, conſiſting of oxyd of tin and phoſphoric acid. In this proceſs both the tin and the phoſphoric acid are divided into two portions, part of the tin is converted into oxyd of tin by deoxygenating a part of the phoſphoric acid, and fuſes with the remainder of the acid into a black glaſs: whilſt the reſt of the tin unites with the deoxygenated phoſphoric acid (that is to ſay, the phoſphorus) into the metallic phoſphuret. This decompoſition takes place at a very moderate heat, ſcarcely more than what is required for the fuſion of tin.

Tin unites with moſt of the metals, and ſome of theſe alloys are much uſed in the arts. Of theſe the moſt important are: the alloy of tin and copper, with other additions, which forms bronze, bell-metal, ſpeculum-metal, &c. and which has been deſcribed under the article COPPER *(Alloys of)*: the alloy of tin and lead in equal parts, which forms the common plumber's ſolder: the alloy of tin, lead, and biſmuth, which forms the very fuſible compounds deſcribed under BISMUTH: the amalgam of tin and mercury uſed in ſilvering mirrors, the proceſs of which is mentioned under the article GLASS, and the alloy commonly called Pewter.

Pewter was formerly more extenſively uſed than, perhaps, any other metallic alloy, being the common material for plates, diſhes, and

[c] Pelletier.

other domestic utensils, but its use is now almost universally superseded by pottery, which is lighter, more easily kept clean, and cheaper, though less durable. The name of pewter has been given to any malleable white alloy into which tin largely enters, and its compotion is so various that hardly any two manufacturers employ precisely the same ingredients and in the same proportion. The finest kind of pewter contains no lead whatever, but consists of tin with a small alloy of antimony, and sometimes a little copper. Wallerius gives the proportions of 12 parts of tin, 1 of antimony, and about $\frac{1}{8}$ of copper.[c] A very fine metal is made of 100 parts of tin, 8 of antimony, 1 of bismuth, and 4 of copper. The use of these additions to the tin is to harden it, and preserve its whiteness, and this fine kind of pewter takes a very high polish, has a beautiful silvery lustre, and is not readily tarnished. Tin, with a little zinc or brass, makes a very fine hard alloy. In all these superior kinds of pewter, the tin forms by far the greater part of the mixture.

It is to be observed that the antimony is so intimately united to the tin, that it is not volatilized when strongly heated, or only in a very small degree, and it is not easily dissolved by any weak acid, so that there is no danger of producing the common effects of this metal in employing this kind of pewter. There is a natural limit to the use both of all the brittle metals, and of copper in alloying tin, which is the brittleness which they impart to the alloy when they exceed certain proportions. But it is not so with lead, which may be mixed with tin in any proportion, and the alloy will remain perfectly malleable; and this, with or without other smaller additions, forms the ordinary pewter, such as is used for measures for liquor, and many smaller purposes, and in other countries of Europe, for many other domestic uses. As lead is by much the cheapest of the two metals, it is the interest of the manufacturer to employ it in as large a proportion as possible, but as much danger to health may be apprehended from this noxious metal, this subject was examined particularly by a commission from the French government of some very able chemists. These gentlemen found, that when wine or vinegar is allowed to stand in vessels composed of an alloy of lead and tin in different proportions, the tin is first dissolved, that the lead is not sensibly oxydated by these liquors, except at the line of contact of the air and the liquor, and that no sensible quantity of lead is dissolved even by vinegar after standing for some days in vessels that contained no more than about 18 per cent. of lead. Therefore as no noxious effect is produced by the very minute quantity of tin which is dissolved, a pewter may be considered as perfectly safe which contains about 80 or 82 per cent. of tin; and where the vessels are employed merely for measures, a much less proportion of tin may be allowed. But the common pewter of Paris was found to contain no more than about 25 or 30 per cent. of tin, and the remainder was lead. The specific gravity of a mixture of tin and lead is *less* than the mean specific gravity of the same proportion of the two metals separately, consequently the bulk of the alloy is greater than the bulks of the metals before union, which is the contrary to what happens in most other alloys. This alloy when in equal parts forms also the common plumbers' solder. When melted it oxydates at its surface with great rapidity, much more than even either of the metals separately, and this oxyd is the basis of the finest *Enamel White*.

The uses of tin are considerable. It is employed for many purposes in fine leaf about the thickness of writing paper, when it is called *Tin-foil*. This is made from the very finest tin which is first cast into an ingot, then laminated to a moderate extent, and afterwards beat out with a hammer, with very great manual labour and skill till it is brought to the requisite thickness, and extended perfectly uniformly without any flaw or break. The other uses of tin are, very largely, for tinning iron and copper, in pewter, solder, and other alloys; and the salts of this metal are employed in dyeing.

TINNING *of Iron and Copper.* See IRON and TIN.

TINCAL. See BORAX.

TINGLASS. See BISMUTH.

TINCTURE. A tincture is commonly understood to be a coloured infusion of any substance in alcohol. It is a preparation much employed in pharmacy with many of the articles of the materia medica, particularly vegetable barks, aromatics of all kind, and many of the resins and gum-resins, which yield to alcohol by infusion that part of their substance in which most of the medicinal virtue resides.

TITANIUM.

This is a metal of a copper red colour, very difficult of fusion, soluble in muriatic acid,

[c] Leonhardi Worterbuch.

and precipitable from this menstruum of a blood red colour by tincture of galls.

§. 1. *Ores.*

Sp. 1. Titanite. *Ruthil*, Wern. *Ruthile*, Broch. *Titane oxydé*, Hauy. *Red Schorl*, of the older mineralogists.

Its colour is dark blood red, passing into reddish brown and copper red. It occurs only crystallized. Its primitive form is a strait prism with a square base. The other forms that it presents are most commonly geniculated, that is, united by one of its extremities with a similar crystal, so that the two together form a very obtuse angle. Sometimes it happens that a crystal is terminated only by a small fragment of another, giving to it the appearance of an imperfect pyramidal termination. Besides the above ascertainable forms, capillary crystals are not unfrequently met with; they are either single, or bundled or grouped together like net work, the interstices being in the form of equilateral triangles. The larger crystals are longitudinally striated. The principal fracture of this mineral is foliated in two directions, with a lustre brightly shining, between semi-metallic and adamantine; its cross fracture is imperfectly conchoidal, passing into uneven, with a glistering lustre. The thin crystals are slightly translucent, the others are mostly opake. Its hardness is nearly equal to that of quartz, but it is brittle and easily frangible. Sp. gr. 4.1—4.24.

It is infusible without addition before the blowpipe, but with borax it forms a glass of a hyacinthine red colour, which by exposure to the external blue flame, becomes successively blue, green, and white. When exposed to a high heat in a charcoal crucible it breaks to pieces, and becomes of a pale brown colour.

The titanite of Hungary has been analysed by Klaproth, and appears to be pure oxyd of titanium mixed with a little silex; that from Spain appears from the same authority to be at least equally pure. The titanite of Aschaffenburg according to Klaproth, and that of Friuli according to Vauquelin, contain a minute portion of manganese and iron.

It occurs near Rosenau in Hungary, and at Cajuelo near Buitrago in New Castille in Spain, implanted in rock crystal, in a mountain of gneiss; at St. Gothard, in the cavities of granite mixed with rock-crystal, adularia, and chlorite: in the Saltzburg mountains imbedded in tremolite; near St. Yrieix in la Haute Vienne in France, in rounded crystals dispersed in an alluvial bed. It has also been found at Sarapulka in Siberia, and in New Granada in S. America.

Sp. 2. Octohedrite. *Anatase*, Hauy.

This mineral has already been described under the name Anatase, which see.

Sp. 3. Calcareo-siliceous titanite. *Titanit*, Klapr. *Nigrine*, Broch. *Titane silicéo-calcaire*, Hauy.

Its colour is brownish-red, blackish-brown, yellowish-brown, and yellowish-white. It occurs massive, disseminated, and crystallized.

Its primitive form is a strait rhomboidal prism, the alternate angles of which measure 137° and 43°.

The other forms that it presents are,

1. A rhomboidal prism with dihedral summits, in which the lateral faces are trapeziums, and the terminal ones triangles.
2. The same with each of the terminal solid angles replaced by two triangular facets, thus making the planes of the prism lengthened hexagons, while those of the summit consist of four triangular and two pentagonal facets.

The crystals are small and commonly imbedded singly. Its longitudinal fracture is foliated, passing into radiated with a glistening lustre; the cross fracture is flat-conchoidal passing into even, and has little or no lustre. It is opake, but sometimes translucent on the edges. It is considerably hard, but brittle and easily frangible. Sp. gr. 3.48—3.51.

When exposed without addition to the blowpipe it only shews a commencement of fusion; in a clay crucible it undergoes no change at an intense heat; but in a charcoal crucible it melts at a high temperature into a black opake scoria.

Specimens of this mineral from Passaw have been analysed by Klaproth, others from Arendahl by Abildgaard, and others from St. Gothard by Cordier, with the following results,

Klapr.	Abild.	Cord.	
33	58.74	33.31	Oxyd of Titanium
35	22.08	28.	Silex
33	20.18	32.	Lime
101	101.00	93.3	

The dark coloured crystals also contain oxyd of iron, according to Vauquelin.

It occurs in the neighbourhood of Passaw in Bavaria, at Buoen in Norway, and at St. Gothard in Switzerland.

Sp. 4. Menachanite. *Menachan & Nigrin*, Wern. *Titane oxydé ferrifère*. Hauy.

Its colour is iron-black paſſing to greyiſh and browniſh-black. It occurs in flattiſh angular grains and ſmall lumps. Its internal luſtre is moderately gliſtening, between ſemi-metallic and adamantine. Its fracture is imperfectly foliated, paſſing into fine-grained uneven. It is opake; is brittle but hard, ſo as not to be eaſily pulverizable. Its ſp. gr. when in ſmall grains is not readily determined, when in larger pieces it amounts according to Klaproth as high as 4.74.

Some varieties are nearly as magnetic as iron ſand; others though not attractible by the magnet are yet capable of affecting the polarity of a ſuſpended magnetic needle; while other varieties have no action whatever on the magnet.

This mineral conſiſts of oxyd of titanium combined with oxyd of iron and a little manganeſe, but the proportions are liable to much variation. The following are the reſults of ſome of the principal analyſes.

From By	Cornwall Klapr.	Aſchaffenburg Klapr.	Ohlâpiân Klapr.	Bavaria Vauq.	Botany Bay Chenevix	Uralian Mountains Lowitz	
	45.25	22.	84.	49.	40.	53.	Oxyd of Titanium
	51.	78.	14.	49.	49.	47.	Oxyd of Iron
	0.25	0.	2.	2.	0.	0.	Oxyd of Manganeſe
	3.5	0.	0.	0.	11.	0.	Silex
	100.	100	100	100	100	100	

It was firſt diſcovered by Mr. Gregor mixed with quartz ſand, in the bed of a rivulet in the valley of Menachan in Cornwall. It has ſince been found imbedded in quartz near Aſchaffenberg in the Speſſart foreſt; alſo at Bodenmais in Bavaria, at Ohlâpiân in Hungary in auriferous ſand; in the Uralian mountains in Siberia, and at Botany Bay in New Holland, &c.

Sp. 5. Iſerin.

Its colour is iron-black inclining to browniſh. It occurs in ſmall angular grains and in rolled pieces, with a rough ſtrongly glimmering ſurface. Internally it is gliſtening with a ſemi-metallic luſtre. Its fracture is more or leſs perfectly conchoidal. It is opake, hard, and brittle. Sp. gr. 4.5.

Before the blowpipe it melts into a blackiſh brown glaſs, which is ſlightly attracted by the magnet. It is ſaid to be compoſed of,

59.1	Oxyd of Titanium
30.1	Oxyd of Iron
10.2	Oxyd of Uranium
99.4	

It has hitherto been found only in the Rieſengebirge, near the ſource of the river Iſer, in granite ſand.

§. 2. *Analyſis of Ores.*

The analyſis of the ores of titanium, though very ſimple, is however very imperfect, as we are hitherto almoſt entirely unacquainted with the compoſition either of the ſalts or oxyds of this metal.

The only menſtruum of ſufficient activity to be employed in the analyſis of theſe ores is fixed alkali, and this is more efficacious when carbonated than when cauſtic. The method followed both by Klaproth and Vauquelin, in the analyſis of titanite, is the following.

a. Having ground the ore to a very minute powder, let it be mixed with five or ſix times its weight of carbonated potaſh, and brought to a ſtate of fuſion in a crucible. The melted maſs when poured out will be of a green colour if any iron and manganeſe are preſent, but otherwiſe of a pearl-grey colour. The fuſed maſs after being pulverized, is to be digeſted in repeated portions of hot water, till every thing ſoluble is extracted, after which there will remain a reddiſh white powder, which is nearly pure carbonat of titanium.

b. The alkaline ſolution contains only a little ſilex and alumine, with the oxyds of manganeſe and iron, which are to be ſeparated in the uſual way.

The calcareo-ſiliceous titanite was thus analyſed by Klaproth.[b]

a. 100 grs. finely pulverized were ignited for an hour with four times their weight of cauſtic potaſh, the reſulting maſs was ſoftened with water, and digeſted with an exceſs of muriatic acid; the whole was thus diſſolved except 12 grs. of ſilex.

b. The muriatic ſolution was decompoſed by

[a] Klapr. Analyt. Eſſ. Vol. I. p. 496. Journ. des Mines, No. 15, p. 12.

[b] Analyt. Eſſ. Vol. I. p. 214.

carbonated potash, and the precipitate thus obtained, after being washed and dried, was again digested with muriatic acid, which left behind 23 grs. of silex.

c. The preceding solution was now combined with caustic ammonia, which threw down 62 grs. of a yellowish white precipitate, that was subsequently reduced by ignition to 33 grs. and was pure oxyd of titanium.

d. The residual fluid when saturated at a boiling heat by mild potash, afforded 33 grs. of carbonated lime.

The menachanite of Bavaria was thus analysed by Vauquelin.[c]

a. 100 grs. finely pulverized were melted in a silver crucible with 400 grs. of caustic potash, during an hour and a half. The fused mass was of a green colour, and afforded with water a green solution, a brick red powder weighing 124 grs. remaining behind.

b. The above 124 grs. were boiled for an hour with caustic potash, and the solution after saturation with muriatic acid was treated with carbonat of potash, which threw down 3 grs. of oxyd of titanium.

c. The residue of the 124 grs. was digested with dilute muriatic acid, which soon acquired a yellow colour, and left behind 46 grs. of a reddish white powder, which was oxyd of titanium.

d. The yellow muriatic liquor was saturated by ammonia, and afforded 50 grs. of brown oxyd of iron.

e. The green alkaline solution (*a*) was supersaturated with muriatic acid, and acquired a bright red colour, which during evaporation entirely disappeared. The saline residue was again perfectly soluble in water, thus shewing the total absence of silex; on the addition of carbonated potash, it yielded a precipitate weighing 2 grs. which was carbonated manganese.

§. 3. *Chemical Properties*.

Several attempts, though with but imperfect success, have been made to reduce titanium to the metallic state. The salt selected for these experiments by Vauquelin,[d] was the carbonat, which after being formed into a paste with fish oil, was placed in a crucible lined with a mixture of clay and charcoal, and exposed for three quarters of an hour to an intense heat. A blackish spungy mass was thus obtained, which in some parts presented a reddish metallic appearance.

In another experiment 100 parts of native titanite were mixed with 50 parts of calcined borax, and an equal quantity of charcoal; the mass thus produced was placed in a lined crucible, and heated for an hour and a half in a forge furnace. An agglutinated brittle mass was thus obtained, the external colour and lustre of which greatly resembled that of copper. Being broken and exposed to the air while it was yet hot, its red colour passed in some places to purple and then to blue. Lampadius[e] is said to have succeeded still more compleatly, by decomposing the gallat of titanium by means of fixed alkali, and strongly heating the oxyd thus obtained in a charcoal crucible. The result of this process is a metallic mass of a dark copper colour with considerable brilliancy; it is very infusible, is composed of slightly cohering scales which individually are moderately elastic. It tarnishes by exposure to the air, is converted by heat to a blue oxyd, detonates with nitre, and is readily acted on by all the strong acids. The metallic mass obtained by Vauquelin, exhibited the following properties with acids. The nitro-muriatic acid converted it superficially into a white pulverulent oxyd. The muriatic acid disengaged a large quantity of hydrogen gas, and a considerable quantity of white flocculent oxyd was observed floating in the liquor. Concentrated sulphuric acid at a boiling temperature, dissolved a portion and converted the remainder to a white oxyd, sulphureous acid gas being disengaged; and the sulphat of titanium thus produced exactly resembled that obtained by the oxyd of this metal.

Titanium appears capable of three states of oxydation, distinguished by the colours blue, red, and yellowish white, the latter being the saturated or per-oxyd. With regard to the proportion of these two ingredients in the different oxyds, scarcely any thing certain is known, only it may be concluded with some probability from the result of an analysis by Vauquelin, that the red oxyd in passing to the state of white oxyd acquires about 18 per cent. From the same experiment by Klaproth indeed, it would be concluded that the augmentation was about 24 per cent.; the difference is not very great, and the truth may perhaps lie between.

The white oxyd when heated acquires a lemon yellow colour, which however disappears again in proportion as it cools. In this state it ields a little to concentrated sulphuric acid, ut is not dissolved by any other liquid men-

[c] Journ. des Mines, No. 19. p. 58. [d] Ditto, No. 15. p. 21. Phil. Mag. Vol. xvii. p. 95.

ſtruum either acid or alkaline. By fuſion with a carbonated alkali it is converted to a carbonat inſoluble in water, and therefore capable of being readily ſeparated by this fluid from the mixed alkali.

Carbonat of titanium is ſoluble in the cold, by either of the three mineral acids moderately diluted, the carbonic acid eſcaping at the ſame time by effervefcence, but on heating theſe ſolutions they are all decompoſed, a white oxyd being precipitated, or rather half ſeparating from the liquid ſo as to make it white like milk. When the nitrat of titanium is thus heated, there is a conſiderable diſengagement of nitrous gas previous to its decompoſition, which ſhows that in this caſe the oxyd becomes inſoluble by abſorbing an additional portion of oxygen. When the muriat of titanium on the other hand is decompoſed by heat, there is a very ſenſible diſengagement of oxymuriatic acid, thus ſhewing that the inſolubility of the oxyd in this caſe is owing to its being deprived of a portion of oxygen. This ſingular circumſtance is further demonſtrated by the ready ſolubility in muriatic acid of the oxyd that has been depoſited from the nitrat.

The alkalies both cauſtic and carbonated decompoſe the ſalts of titanium, throwing down a white oxyd in the one caſe, and a carbonated oxyd in the other. The arſenic and phoſphoric acids alſo throw down a white precipitate. The tartareous and oxalic acids afford a white precipitate, reſoluble in an additional portion of acid. Hydroſulphuretted water occaſions no turbidneſs, but an alkaline hydroſulphuret affords a dirty browniſh green precipitate; the green colour however is probably owing to a ſlight contamination of iron. Pruſſiat of potaſh affords a copious precipitate of a green colour, which does not become blue by expoſure to the air according to Vauquelin, of a graſs-green colour mixed with brown according to Klaproth, but of a dirty yellowiſh brown according to Lowitz; a muriatic ſolution of the titanium in anataſe was obſerved by Vauquelin to give with pruſſiat of potaſh a cheſnut brown precipitate. Tincture of galls, or gallic acid, throws down a bulky browniſh red precipitate, which, except the ſolution is much diluted, in a ſhort time becomes clotted like blood: this precipitate when waſhed and dried greatly reſembles kermes mineral.

If into a vial filled with muriat of titanium there be put a ſtick of tin, and the vial be cloſed by a ſtopper, a faint roſe colour will ſoon be viſible in that part of the ſolution adjacent to the tin, which by degrees will deepen to an amethyſtine red, and extend through the whole liquor. If a ſtick of zinc be ſubſtituted to the tin, the colour of the ſolution will be firſt violet and at length indigo-blue: this coloured liquor when gently warmed in a ſhallow veſſel in contact with the air, will loſe its colour, and depoſit a bulky white precipitate, again ſoluble in muriatic acid, and apparently differing in nothing from the original muriatic ſolution.

It is not known whether titanium combines with ſulphur, it may be made however to unite with phoſphorus in the following way. Mix the phoſphat of titanium with charcoal and borax, and heat the maſs ſtrongly in a blaſt furnace, the reſult will be a button of titanium of a pale white colour, and metallic luſtre.

Various attempts have been made by Vauquelin to alloy titanium with the other metals, but wholly without ſucceſs, where lead, arſenic, copper and ſilver, were employed, and with only very dubious ſucceſs, when iron was made uſe of.

Both the white oxyd and titanite in ſubſtance, according to Klaproth, afford when mixed with enamel flux, a ſtraw-yellow colour, and it appears from Le Lievre, that it was uſed in the porcelain manufactory at Sévres as an ingredient in the rich browns, but the difficulty of obtaining from it an uniform tint, has at length occaſioned it to be abandoned.

TOADSTONE. See Trap.

TOEPFERTHON. See Clay potters'.

TOPAZ. Topas, *Wern.* Topaze, *Hauy* and *Broch.* Topaz of Brazil, of Saxony, and of Siberia. Occidental Topaz.

Its moſt uſual colour is wine yellow of different degrees of intenſity; it alſo occurs nearly colourleſs, yellowiſh and bluiſh white, and pale ſky-blue, alſo greeniſh-grey, roſe-red, and peach-flower red.

It is found in maſs, diſſeminated, in rolled fragments, and cryſtallized. Its primitive form is a ſtrait priſm, with rhomboidal baſes, the alternate angles of which meaſure 124° and 56°.

The other varieties of cryſtallization that it preſents are the following.

1. An eight-ſided priſm, the planes of which join one another, forming two oppoſite angles of 124°, two others of 93°, and four others of 161°. The priſm is terminated by tetrahedral pyramids.

2. The preceding, with the edges of the terminal pyramid that adjoin the two ſmalleſt angles of the priſm very deeply truncated, ſo as to form ſometimes a hexahedral, and ſometimes

even a cuneiform ſummit; the former termination is obſervable in the Braſilian, and the latter in the Siberian topazes.

3. The preceding, with a hexahedral ſummit deeply truncated, ſo as to form a regular hexagonal plane.

4. The preceding, with the edges of the priſm that are adjacent to the two ſmalleſt angles replaced each by two ſecondary planes, thus forming a dodecahedral priſm.

5. The preceding, with the lateral, and ſometimes the vertical edges of the ſummit bevilled.

The cryſtals are generally ſmall and middle ſized; their lateral faces are generally longitudinally ſtreaked, and ſometimes convex. The luſtre both externally and internally, is uſually brightly ſhining, vitreous. The croſs fracture is ſtrait lamellar, the longitudinal is ſmall and imperfectly conchoidal. It varies from tranſparent to tranſlucent, and poſſeſſes a double refraction. When in maſs it occurs in coarſe and fine granular diſtinct concretions. It ſcratches quartz but is inferior in hardneſs to the ruby. It is eaſily frangible. Sp. gr. 3.46—3.56.

It is infuſible *per ſe* before the blowpipe, but melts without intumeſcence by the aſſiſtance of borax. The Saxon topaz by a gentle heat becomes colourleſs without undergoing any other change, and in this ſtate is ſometimes ſold for diamond; at a higher heat however it becomes opake. The Brazilian topaz, when ignited in a crucible, becomes of a roſe-red colour, and is then often called by the jewellers Brazilian ruby.

The Brazilian and Siberian topazes are rendered electric by heat.

According to the firſt analyſis of this mineral by Vauquelin, its component parts appeared to be,

31	Silex
68	Alumine
99	

Klaproth however afterwards detected the preſence of fluoric acid in conſiderable abundance, which induced a ſecond analyſis of it by Vauquelin,[a] according to which it conſiſts of,

29	Silex
50	Alumine
21	(or thereabouts) Fluoric acid
100	

Topaz occurs at Schneckenſtein in Saxony mixed with quartz, black ſchorl, mica and lithomarga, forming an aggregate which has obtained the name of topaz rock. It is found in Bohemia at Schlackenwald in veins mixed with tinſtone, fluor ſpar and miſpickel. The Siberian topazes are found in the Uralian mountains, near Ekaterinenburg, and in Daouria in the mountain Odontchelon, imbedded in graphic granite, and accompanied by blackiſh quartz and aquamarine. Topaz alſo occurs in Brazil, and at Muckla in Natolia, alſo in Pegu and Ceylon.

It ranks as one of the gems, but is not very highly valued.

TOPAZ Oriental. See CORUNDUM.

TOPAZ falſe. See FLUOR SPAR and QUARTZ.

TOPFSTEIN. See POTSTONE.

TOUCHSTONE. See KIESELSCHIEFER.

TOURMALINE. See SCHORL in the Addenda at the end of the volume.

TRAGACANTH GUM. See MUCILAGE.

TRANSFER. An article of apparatus, for a deſcription of which ſee the Appendix.

TRAP.

The term Trap is Swediſh, and ſignifies a ſtair. It was firſt applied about ſixty years ago, by ſome Swediſh mineralogiſts to deſignate a certain claſs of mountains, compoſed of nearly horizontal ſtrata with perpendicular breaks, which thus preſented a rude reſemblance to a flight of ſtairs. In conſequence of the vagueneſs of this eſſential character, many ſpecies of rock differing very much from each other were called by the ſame name, and inextricable confuſion would ſoon have enſued, if Werner had not by adopting and reſtricting the term, beſtowed on it a definite meaning.

According to Werner there are three diſtinct claſſes or formations of rocks to which the term trap may be applied. Of theſe, the firſt claſs belongs to the primitive mountains, the ſecond to the tranſition mountains, and the third to the ſecondary mountains.

§ 1. *Primitive Traps.*

The primitive traps are compoſed eſſentially of hornblende, not unfrequently mingled with feldſpar, and more rarely with pyrites and mica. There are four diſtinct ſpecies of rocks belonging to this formation, namely common hornblende, ſchiſtoſe hornblende, primitive grünſtein and ſchiſtoſe grünſtein.

The *common hornblende* rock is no other than the ſubſtance already deſcribed in the article

[a] Journ. des Mines, No. 96, p. 469.

Hornblende. It is sometimes a congeries of large imperfect crystals, but more generally of grains, which last are often so minute as to give the whole rock a compact appearance.

Schistose Hornblende rock is for the most part composed of the substance from which its name is derived; it is however occasionally mixed with quartz, actynolite and pyrites. This rock does not exclusively belong to the trap formation as it forms subordinate beds in gneiss, micaceous schistus, and argillite. It passes sometimes into grünstein.

Primitive grünstein, or green stone, so called from its colour, is an aggregate of hornblende and felspar. It differs in little or nothing except its situation from sienite. There are three varieties of this rock; in one the hornblende and felspar are intimately and immediately aggregated and its texture is simply granular; in the second variety, the grains of which it is composed are smaller than in the preceding, and in this aggregate, as in a paste, are imbedded crystals of felspar; hence its texture is at the same time finely granular and porphyritic; in the third variety the particles of felspar and hornblende composing the paste, are so minute as to be indistinguishable, hence its fracture is compact and even splintery; in this are imbedded crystals of felspar. The green antique porphyry belongs to this variety.

Schistose grünstein is composed of compact felspar and hornblende in nearly equal proportions, mixed with a little mica, and, more rarely, with quartz: it has a schistose texture.

This rock is not peculiar to the primitive trap formation, being found sometimes to alternate with argillite.

Grünstein is not unfrequently traversed by metalliferous veins.

§ 2. *Traps of Transition.*

The principal material of the rocks that belong to this formation is granular grünstein; but in the transition traps the mixture of the ingredients is more intimate, the grain is finer, and the mass appears more homogeneous. The two following are its principal varieties.

Amygdaloid.—Toadstone, Mandelstein.

The mass of this rock is schistose hornblende or schistose grünstein in a state of semi decomposition resembling Wakke or fine ferruginous clay. It contains a number of globular cavities from the size of a pea to that of a small apple; of these cavities some contain nothing but air, and are coated on the inside with a kind of varnish; others contain balls of calcareous spar, quartz, and chalcedony, the latter composed of concentric layers round a hollow nucleus lined with crystals of quartz. The toadstone of Derbyshire is considered by Werner to belong to this variety.

Globular Trap. Kugeltrap.

This is composed of schistose grünstein in a state of semi-decomposition, arranged in spheroids of various magnitudes, and composed of thick concentric lamellar distinct concretions.

The traps of transition appear not to be stratified; they form solitary conical mountains in the vicinity of transition limestone, and contain very few metallic veins.

§ 3. *Secondary, or Floetz Traps.*

The rocks or strata belonging to the secondary trap formation may be divided into those which are peculiar and characteristic of it, and those which are accidental. The former are basalt, wakke, basaltic trap, secondary amygdaloid, klingstein porphyry, graustein, and secondary grünstein. Among the latter may be classed, rubble and sandstone, clay, coal, and bituminous wood.

Basaltic rock, is composed for the most part of the mineral already described in the article basalt. It is usually porphyritic, and then contains crystals or grains of felspar, olivine, augite, basaltic hornblende, magnetical iron, leucite, quartz, and, rarely, mica, actynolite, and chalcedony. Sometimes it assumes the amygdaloidal structure, and its cavities are then either empty or filled with zeolite, steatite, calcareous spar, and even sometimes with water. Of all the rocks belonging to the secondary trap formation, basalt is of the most frequent occurrence; it forms by itself whole mountains, and the entire series of rocks with which it is associated, may be with much propriety, and is actually by some mineralogists, denominated the basaltic formation.

Wakke rock is composed of the mineral bearing this name, mixed with crystals of basaltic hornblende, and particularly with hexagonal plates of black mica, by which, and by the absence of olivine and augite, it is distinguished from decomposing basalt.

Basaltic Tufa is the result of the decomposition or rather of the disintegration of certain beds of basalt; it consists of pieces of basalt, fragments of olivine, and vegetable remains agglutinated together by an argillaceous cement.

Secondary amygdaloid, appears to have for a base decomposed grunstein, which is often penetrated by siliceous particles; sometimes it

passes into wakke and sometimes into basalt. The spheroidal cavities of this amygdaloid are either empty or filled with green earth, zeolite, calcareous spar, chalcedony, &c.

Klingstein porphyry consists of a base of Klingstein in which are imbedded crystals of felspar, and sometimes of hornblende. It passes frequently into basalt.

Secondary grunstein, like the primitive and transition grünstein is composed of hornblende and felspar, but in this the grains have a less perfect crystalline appearance.

Graustein, or grey stone, is a rock composed of very minute grains of hornblende and felspar in a state of such intimate mixture, as to have the appearance of an almost uniform mass of an ash-grey colour. It contains olivine and augite.

The proper base to the secondary trap formation, or in other words the substance which appears to have immediately preceded it in the order of formation, is secondary limestone; it is however not unfrequently found resting on sandstone, on argillite, on gneiss, and even on granite.

The general order in which the strata of this formation are arranged relatively to each other, is the following, viz. coarse sand, fine sand, sandy clay, unctuous clay, wakke, basalt, amygdaloid, klingstein porphyry, grünstein, and graustein; it hardly ever happens however that all these strata are met with in the same mass of mountain.

No metallic veins are found in this class of mountains, but the remains of vegetable and marine organized bodies are of frequent occurrence.

TREMOLITE. *Tremolith*, Wern. Broch. *Grammatite*, Hauy.

Of this mineral there are the three following subspecies.

1 *Subsp.* Common Tremolite.

Its colour is greenish-white, sometimes greyish, reddish or yellowish-white, also pearl-grey, smoak-grey, and pale brownish green. It occurs in mass or crystallized. Its primitive form is that of an oblique rhomboidal prism, the alternate angles of which are 127° and 53°. It also presents the following varieties.

1. The primitive tetrahedral prism with dihedral summits. Each summit is composed of two isosceles triangles joined by their bases, having their apexes adjacent to the acute angles of the prism.

2. The preceding with the acute edges of the prism truncated, whence results a hexahedral prism, with the terminal triangles, composing the summit, also truncated at their apexes, or in other words converted into trapeziums.

3. The same as var. 1, with both the acute and obtuse edges of the prism truncated, whence results an eight-sided prism with dihedral summits, the planes of which are triangles with all their angles truncated, or hexagons.

The crystals are middle-sized, longitudinally striated, confusedly grouped together, and imbedded; internally, tremolite is glistening or shining, with a pearly lustre. Its fracture is broad striated with parallel or divergent rays, and passes into foliated. Its cross fracture is uneven. It presents granular or wedge-shaped distinct concretions. It is translucent, when crystallized semi-transparent; is generally hard enough to scratch glass, is brittle, and easily frangible.

2 *Subsp.* Glassy Tremolite.

Its colour is greyish and yellowish-white, rarely greenish or reddish. It occurs in mass, or in elongated needle-shape crystals. Internally it is more or less shining with a pearly lustre. Its longitudinal fracture is divergingly radiated passing into fibrous; its cross fracture is uneven. It is composed of prismatic distinct concretions the surfaces of which are slightly striated. It is translucent, moderately hard, brittle, and easily frangible.

It melts before the blowpipe without addition into a white scoria. Its component parts, according to an analysis by Klaproth, are

65.	Silex
10.33	Magnesia
18.	Lime
0.16	Oxyd of iron
6.5	Water and carbonic acid
99.99	

3 *Subsp.* Asbestous Tremolite.

Its colour is yellowish, reddish, greenish, or greyish white. It occurs in mass and in capillary crystals. Its internal lustre is glistening and pearly. Its fracture is strait and fine fibrous either simply divergent or bundled. It presents granular and wedge-shaped distinct concretions. It is translucent on the edges, is soft and easily frangible.

The softer varieties of tremolite are phosphorescent both by heat and by friction.

Tremolite was first discovered by Pini in the valley of Tremola among the Italian Alps. It also occurs in Mont St. Gothard in Switzer-

land, in the Tyrol, Tranfylvania, Moravia, and at Langenfeldt in Saxony; alfo in Siberia near Lake Baikal, in the Shetland iflands, and in the caftle rock of Edinburgh.

It occurs principally in primitive mountains, imbedded in dolomite or granular limeftone, and mixed with mica and talc. It is alfo found in the fecondary trap-formation, accompanied by prehnite.

TRIPHANE. *Spodumene*, D'Andrada and Werner.

Its colour is apple-green, or greenifh-white. It occurs in mafs. Its longitudinal fracture is fhining, its crofs fracture is gliftening, with a pearly luftre. Its fracture is foliated in two directions; the crofs fracture is fine grained uneven. The fragments are indeterminate, or in the form of very oblique rhombs. It is tranflucent, moderately hard, and eafily frangible. Sp. gr. 3.21.

Before the blowpipe it becomes yellow and fplits into thin plates, and then melts into a tranfparent greyifh glafs.

It has hitherto been found only in the mines of Uton, near Dalero in Sweden, in veins with quartz and back mica.

TRIPOLI. *Trippel*, Wern.

Its colour is yellowifh-grey, paffing into afh-grey and reddifh-brown. It occurs in mafs, and is without luftre; its fracture is coarfe-grained earthy, paffing into obfcurely flaty. It is foft, often friable; is meagre and rough to the touch, and does not adhere to the tongue.

It is fcarcely fufible before the blowpipe without the affiftance of borax. It is compofed, according to M. Haafe, of

90	Silex
7	Alumine
3	Oxyd of iron
100	

It was formerly brought to Europe from Tripoli in Africa, but has fince been found in Saxony, at Pottfchappel near Drefden, in Derbyfhire, in Flanders, Switzerland, Heffe, Weftphalia and Ruffia. It occurs in veins and beds in fecondary rocks, and probably fometimes is a pfeudo-volcanic production.

It is largely employed in polifhing metals, marble, glafs, and other hard bodies.

TUBE OF SAFETY.

An article of chemical apparatus, for an account of which fee the APPENDIX.

TUFA calcareous. *Kalk Tuff*, Wern.

Its colour is yellowifh-grey or fmoke-grey. It occurs fometimes folid, but generally porous and marked with impreffions of reeds, mofs, and other vegetables. Its luftre, when it has any, is faintly glimmering. Its fracture is fine grained uneven, paffing into earthy. It is foft, eafily frangible, and not much heavier than water.

It effervefces with acids, and is little elfe than carbonat of lime.

It occurs in alluvial land, being depofited by water impregnated with carbonat of lime.

The more compact kinds are employed in building, for which their lightnefs well adapts them.

TUNGSTEN. *Scheelium.*

Tungften is a hard brittle granular metal, very difficultly foluble in the acids, combines with the alkalies, and is converted from yellow to blue oxyd by muriated tin.

§. 1. *Ores.*

Sp. 1. TUNGSTEN. *Schwerftein*, Wern.—*Scheelin calcaire*, Hauy. *Goffan*, of the Cornifh miners.

Its colour is greyifh or yellowifh-white, paffing into yellowifh-grey; it is often fuperficially tarnifhed to dark pearl-grey or yellowifh brown. It occurs in mafs, diffeminated, and cryftallized. Its primitive form, according to Hauy, is the cube; but the ufual form that it prefents is the octohedron, either regular, or bevilled at the common bafe of the pyramids, or cuneiform. Its cryftals are middle-fized or fmall. The lateral planes of the cryftals are fmooth and brightly fhining with a nearly adamantine luftre. Its fracture is imperfectly foliated, paffing into conchoidal and uneven; that of the maffive varieties is granular and fplintery. It fometimes occurs in large or fmall grained diftinct concretions. The cryftallized is tranflucent, rarely tranfparent; the maffive is opake. It may be fcraped without difficulty by a knife, is eafily frangible, but not particularly brittle. Sp. gr. 6.01. = 5.57.

Before the blowpipe, without addition, it crackles and becomes opake, but is not fufible. When pulverized and digefted with nitric or muriatic acid it leaves a lemon-yellow refidue, which is tunftic oxyd. This mineral has been analyfed, firft by Scheele, then by the Elhuyars, and laftly by Klaproth, with the following refults.

From Bitsberg. By Scheele.		Schlackenwald. Elhuyars.		Schlackenwald. Klaproth.		Cornwall. Klapr.	
65.	—	68.	—	77.75	—	75.25	Oxyd of Tungsten.
31.	—	30.	—	17.6	—	18.7	Lime.
4.	—	0.	—	3.	—	1.5	Silex.
						1.25	Oxyd of Iron.
						0.75	Ditto of Manganese
100.		98.		98.35		97.45	

Tungsten is rather a rare mineral. It occurs in metallic veins in primitive mountains, accompanied by tinstone, hæmatite, wolfram, quartz, mica, steatite, &c. It is found at Bitsberg in Sweden, Schlackenwald in Bohemia, and Pengilly in Cornwall.

Sp. 2. Wolfram. *Wolfram*, Wern. Broch. *Schéelin ferrugineé*, Hauy.

Its colour is brownish-black, greyish-black, and dark reddish-brown, often with a greenish iridescent tarnish. It occurs massive and crystallized. Its primitive form is a rectangular parallelopiped; besides which it presents the following varieties:

1. A tetrahedral prism, with dihedral summits, with the common edges of the summits and prism truncated.

2. A compressed tetrahedral prism, with bevilled dihedral summits, obliquely truncated.

3. The same, with the lateral edges of the prism also bevilled.

The crystals are of middle-size or large, sometimes solitary, but most commonly grouped together in an irregular manner, and often very indistinct. Externally they are glistening, internally they are brightly shining with a metallic lustre. Its longitudinal fracture is strait lamellar, its cross fracture is granular uneven. It occurs sometimes in curved lamellar distinct concretions, with alternate saliant and re-entering angles. It is opake, gives a reddish-brown powder, may be readily scraped with a knife, is brittle and easily frangible. Sp. gr. 7.12.

Before the blowpipe it crackles and becomes of a darker colour, but does not melt. It has been analysed by the Elhuyars, by Wiegleb, by Klaproth, and by Vauquelin, with the following results:

Elhuy.		Wiegl.		Klapr.		Vauq.	
65.	—	35.75	—	46.9	—	67.	Yellow oxyd of Tungsten.
22.	—	32.	—	0.	—	6.25	Oxyd of Manganese.
13.5	—	11.	—	31.2	—	18.	Oxyd of Iron.
2.0	—	0.	—	0.	—	1.5	Silex.
102.5		78.75		78.1		92.75	
		21.25		21.9		7.25	Loss

It occurs in veins in primitive mountains, generally accompanied by tinstone. It is found at Zinnwald, Graupen, and Schlackenwald, in Bohemia; at Ehrenfriedersdorf, Geyer, and Altensberg in Saxony; at St. Leonard, departement de la Haute Vienne in France; Poldice in Cornwall.

§. 2. *Assay and Analysis.*

1. The analysis of tungsten is very simple; the most successful method of performing it is that which was invented by Scheele,[a] and has since been adopted by Klaproth,[b] viz. After the mineral has been finely pulverized, let it be digested in moderately strong nitric acid, by which a part will be dissolved, and the residue will acquire a yellow colour; then pour off the nitric solution, edulcorate the residue, and afterwards digest it in liquid ammonia. This latter menstruum will take up a portion and change the colour of the remainder to white: proceed in this manner, alternately employing nitric acid and ammonia, till every thing soluble is taken up; what remains is generally nothing but a small quantity of *silex*.

The nitric solution is now to be treated with liquid caustic ammonia, by which any oxyd of *iron* or *manganese* that may be present will be thrown down; which being separated by the

[a] Essays.

[b] Analyt. Ess. vol. ii. p. 33.

filter, carbonat of soda is to be added to the solution in order to precipitate the *lime:* this, when washed and dried, is pure carbonat, from which the amount of pure lime may be deduced by the common rule of proportion.

The ammoniacal solution contains only ammonia and oxyd of tungsten; it is therefore to be evaporated to dryness, and the residue gently ignited in a platina crucible; by this process the ammonia will be destroyed and driven off, and a pure yellow oxyd of *tungsten* will be left behind.

2. The analysis of Wolfram is to be conducted nearly in the same manner as the preceding. Having reduced the ore to fine powder, it is to be digested with nitro-muriatic acid; a pretty copious disengagement of nitrous gas will ensue, part of the powder will be dissolved, and the remainder will be of a yellowish colour: the nitro-muriatic solution being poured off, the residue is to be treated with liquid ammonia; thus alternately making use of these two menstrua till nothing but a few grains of quartz remains behind.

The muriatic solution, containing the oxyds of iron and manganese, is to be mixed with perfectly neutralized carbonat of potash, till the liquor begins to grow turbid; being then gently boiled for a minute or two, a copious precipitation of oxyd of iron will take place. The clear liquor being then neutralized with a solution of pearlash, will deposit a cream-coloured precipitate, consisting of carbonated manganese, with a little oxyd of iron, which is to be separated as already described in the article MANGANESE.

The ammoniacal solution contains the oxyd of tungsten, which may be procured in the form of a yellow powder, by evaporating to dryness and subsequent ignition in a platina crucible.

3. It remains to make a few remarks on the particulars of the analyses quoted in the preceding section.

The analyses of tungsten by Scheele and the Elhuyars agree very nearly with each other, though they differ very widely from those by Klaproth. It is to be observed however that the analysis attributed to Scheele is merely an inference from a single experiment, in which 80 grains of tungsten were alternately treated with nitric acid and ammonia; the nitric solution, when saturated by carbonated potash, afforded 45 grs. of carbonat of lime; but no mention is made of the proportion of tungsten contained in the ammoniacal solution. The particulars of the analysis by the Elhuyars we have not seen; but those by Klaproth are stated at length in his Analytical Essays, and appear to be liable to no objections.

With regard to the four analyses of Wolfram, it is remarkable that in those by Wiegleb and Klaproth there is a deficiency amounting to between 21 and 22 per cent. The particulars of these two analyses we have not been able to meet with, and therefore can only account for the deficiency by supposing that the old method of decomposing this substance by fusion with nitre or fixed alkali has been resorted to; in which case the oxyd of tungsten being rendered soluble in water by combination with alkali and the precipitating acid, may have partly escaped in the washings.

The method employed by Vauquelin[c] and the Elhuyars[d] was the alternate application of muriatic acid and liquid ammonia, and the following was the *state* in which the component parts were estimated, viz. yellow oxyd of tungsten, magnetic oxyd of iron, and black oxyd of manganese. But though these metals were obtained from the ore at the above-mentioned states of oxydation, it does by no means follow that they existed in this state in the ore itself. First with regard to the iron; this it is evident does not exist in the Wolfram as black oxyd; for the mineral is wholly incapable of affecting the magnetic needle. Secondly, with regard to the manganese; this probably exists in the wolfram at a low state of oxydation, for when digested with muriatic acid there is no perceptible odour of oxy-muriatic acid, and its colour is very considerably deepened by gentle calcination. Thirdly, with regard to the tungsten; in the analyses both of Vauquelin and the Elhuyars it is mentioned, that the colour of the residue after digesting wolfram with muriatic acid, was yellow; from which it would appear that the tungsten existed in the state of yellow oxyd in the ore. It is with the utmost diffidence that we oppose our own experiments to those of so accurate and able a chemist as Vauquelin, yet as they were carefully made we cannot avoid stating them. The wolfram that we operated on was from Cornwall, and of a dark liver colour. When digested with nitro-muriatic acid, there was a copious production of nitrous gas, the liquor became of a high wine colour, and had taken up oxyd of iron and

[c] Journ. des Mines, No. 19. p. 17.
[d] Chemical analysis of Wolfram, &c. by the Elhuyars, translated by C. Cullen, p. 30.

manganese, but nothing else. The residue consisted of undecomposed wolfram, mixed with a yellow powder, which last was entirely taken up by liquid ammonia. On the other hand, when strong and very pure muriatic acid was employed, the liquor acquired a brownish green colour, no oxy-muriatic acid gas was given out, and the solution, besides iron and manganese, contained oxyd of tungsten, which was thrown down by the addition of distilled water, in the form of a pale yellowish green powder; this powder was not resoluble in muriatic acid; it became white on the addition of ammonia, but was very sparingly soluble. Its greenish tinge was changed to bright yellow by nitric acid, nitrous gas being disengaged. The decomposed residue of the ore not taken up by muriatic acid, was of a dirty green colour, but on the addition of ammonia became of a deep blue, which blue powder was insoluble in ammonia. We cannot therefore but conclude that the acid employed by Vauquelin was mixed with nitric acid; and that the tungsten exists in wolfram in the state of blue sub-oxyd.

§. 3. *Reduction of ores.*

Metallic tungsten not being applied to any use, the only attempts to reduce it have been made on small quantities in the laboratory. The Elhuyars were the first who obtained it in the reguline state.[e] For this purpose they put 100 grains of the yellow oxyd into a crucible lined with charcoal, and gave it a strong heat for an hour and a half. The crucible was broken when cold, and was found to contain a friable congeries of metallic globules, of the colour and lustre of steel, and weighing 60 grs. Vauquelin[f] afterwards repeated the experiment, by first mixing the yellow oxyd with oil, and then exposing it in a lined crucible for two hours to the violent heat of a forge furnace: he obtained a darkish grey mass, consisting of a number of small globules. In another experiment, where the oxyd and oil was mixed with boracic acid, he obtained a porous mass of a greyish white colour, with the cavities lined with minute, brilliant, metallic crystals. A third method has been practised with success by the writer of this article, assisted by Mr. Allen. 240 grs. of tunstat of ammonia, in acicular crystals, were put into a crucible lined with charcoal, and exposed for two hours to a powerful wind furnace; there was thus produced a slightly cohering mass, weighing 161 grs. of roundish grains, about the size of a pin's head, with a very brilliant metallic lustre.

§. 4. *Physical and Chemical properties.*

The colour of tungsten is a light steel-grey, with a brilliant metallic lustre: it is in the form of minute grains, slightly agglutinated; it is very hard, yielding with difficulty to the file. Its sp. gr. according to the Elhuyars, is = 17.6, according to an experiment of my own is = 17.33. It does not at all affect the magnetic needle: when exposed to a stream of oxygen gas on charcoal it burns with a yellow flame without melting, and is entirely volatilized in the form of a thick vapour, which when collected is the yellow oxyd of this metal.

Neither the muriatic nor sulphuric acids have any perceptible action on this metal, even at a boiling heat; but when mixed with a little nitric acid, a disengagement of nitrous gas ensues, and the metal is partly dissolved, and partly diffused through the liquor in the state of yellow oxyd. This solution undergoes no change on dilution with water; by the addition of a few drops of prussiat of potash, its colour becomes a deep somewhat iridescent green, but no precipitation takes place; by caustic potash it is changed to a brown olive, and the green colour is again restored by the addition of a few drops of nitric acid.

By a red heat, with access of air, tungsten is readily converted into a lemon yellow oxyd. 100 parts of the metal afford, according to the Elhuyars, 124 of oxyd.

The above are all the facts hitherto published concerning metallic tungsten, those which follow being the results of experiments made on the oxyd of this metal, as extracted from its ores, without having been subsequently reduced to the reguline state.

There are two oxyds of tungsten, the yellow or per-oxyd, and the blue or sub-oxyd. The former may be prepared in various ways; first, as already mentioned, by calcination of the metal; secondly, by fusing two parts of wolfram with three of nitre, and digesting the saline mass thus produced in hot water; the liquor contains the oxyd of tungsten combined with potash, and holding in solution a little oxyd of manganese: by exposure to the air for a day or two, the latter oxyd is precipitated; the clear liquor being then evaporated to dryness is to be digested with three or four successive portions of nitric acid, by which the alkali will

[e] Chemical analysis of Wolfram, &c. p. 58.

[f] Journ. des Mines, No 19, p. 24.

be taken up, and the yellow oxyd of tungsten will remain behind, still however combined, perhaps, with a little alkali. A third method, and upon the whole the best, of preparing this oxyd, is by calcining the crystallized tunstat of ammonia in an open crucible of platina, by which the alkali will be entirely driven off and destroyed, and perfectly pure oxyd will remain behind: 100 parts of this salt afford, according to Vauquelin, 78 of yellow oxyd.

The proportion of oxygen in the yellow oxyd has not yet been ascertained with much precision. The Elhuyars obtained from 100 parts of oxyd 60 parts of metal, according to which the oxyd contains 40 per cent. of oxygen; but on the other hand, from 100 parts of metal they obtained by calcination only 124 parts of oxyd, which would make the oxyd contain only 19.4 per cent. of oxygen. This latter proportion appears the most worthy of credit, both from the circumstances of the experiment, and because it does not very much differ from the proportions obtained by combining the results of two other experiments, the one by Vauquelin and the other by myself, according to which 100 parts of tunstat of ammonia afford 78 of yellow oxyd, and 240 parts of the same salt afford 161 of metal, which would give for the composition of the yellow oxyd 86 parts of metal to 14 of oxygen.

The yellow oxyd is insipid and inodorous: its sp. gr. is = 6.12. When exposed to the blowpipe in a platina spoon, it acquires a deep green colour; it gives a deep blue when fused with microcosmic salt; when heated on charcoal it becomes of a dark bluish black. By a strong heat in a close crucible its colour is changed to a blackish grey, according to Vauquelin; but according to the Elhuyars it forms a spungy mass of a bluish black colour, and covered superficially with minute crystals; its sp. gr. is increased to 9 55, and by calcination in a muffle it again acquires a yellow colour, and its weight is increased by 2 per cent. (It is to be observed however, that the oxyd employed by the last mentioned chemists was prepared according to the second of the methods above described, and therefore might possibly contain a little potash). The yellow oxyd when digested with a little dilute muriat of tin, acquires a deep blue colour, and if in this state it is removed into dilute nitric acid and warmed, nitrous gas will be given out, and the yellow colour will be again restored, thus clearly showing that the blue powder is the sub-oxyd of this metal.

The yellow oxyd even if distilled repeatedly to dryness with nitric acid, undergoes no apparent alteration. It is entirely insoluble in water, but if rubbed in a mortar with this fluid it forms a yellow emulsion, which passes turbid through the pores of filtering paper, and requires very long rest before it becomes clear. This yellow fluid has no taste, nor does it at all redden litmus or other blue vegetable substances; it may therefore be questioned how far it has a title to its usual appellation, tunstic acid, (the tunstic acid of Scheele being a very different substance, as we shall show presently), as, however it unites with the alkalies, and dislodges carbonic acid from some of its combinations, it may without impropriety be considered as at least acting the part of an acid.

The yellow oxyd is entirely insoluble in the sulphuric, nitric, or muriatic acids; by digestion with acetous acid it is converted into the blue oxyd, but is not dissolved. Caustic potash either in the dry or moist way combines with the yellow oxyd, forming a salt with excess of alkali, readily soluble in water, from which by evaporation may be obtained a glittering powder, but without any appearance or regular crystallization. *Tunstat of Potash* thus obtained has a somewhat caustic metallic taste, is deliquescent in a moist air, and is easily soluble in water. When supersaturated with nitric acid a white precipitate falls down, which, when washed with cold water and dried, presents the following properties[g]. It is acid to the taste, colours litmus red, and is soluble in about 20 parts of boiling water. The solution when mixed with lime water, and boiled, deposits a heavy white powder which appears to be tunstat of lime. When saturated with an alkali it yields by evaporation a crystalline salt. When boiled with filings of zinc, tin, or iron, the liquor becomes of a deep blue, and deposits a precipitate of the same colour. Nitric or muriatic acid when boiled on the above mentioned white precipitate, change its colour to yellow, as sulphuric acid does to blue. From the above properties it was considered by Scheele as the pure acid of tungsten, but later experiments have proved that this was a mistake, it being a triple salt composed of oxyd of tungsten, potash, and nitric acid. The composition of this salt is satisfactorily shewn by an experiment of the Elhuyars.

[g] Scheele's Ess.

To a solution of it in water was added lime-water as long as any precipitation ensued: the precipitate being washed and dried, was found to be pure tunstat of lime: the residual liquor being then evaporated, afforded on cooling, crystals of nitre.

Tunstat of potash is decomposable by every other acid as well as by the nitric, and the white precipitate is in all these cases a triple salt, composed of potash, oxyd of tungsten, and the precipitating acid.

If the yellow oxyd of tungsten is digested with carbonated instead of caustic potash, an effervescence is produced by the disengagement of carbonic acid, and the resulting tunstat of potash is the same as that already described.

Tunstat of soda is produced by digesting the yellow oxyd with caustic or carbonated soda, and evaporating the liquor, which deposits the salt in question in the form of lengthened hexahedral plates. The taste of this salt is acrid and metallic; it changes the colour of red vegetable infusions as the alkalies do: it is soluble in four times its weight of cold, and in twice its weight of boiling water: it is decomposable by the acids forming with them triple salts analogous to those of tunstat of potash: the phosphoric acid however occasions no precipitate, forming with it a very soluble triple salt, which is not decomposed even by sulphuric acid.

Tunstat of soda is not rendered turbid by the sulphats either of potash or of magnesia; but alum and the muriats of lime and barytes throw down a white precipitate: alkaline prussiat of potash occasions no turbidness in this salt, but on the addition of a little muriatic acid a brown precipitate falls down, which is soluble in a large proportion of water. Neither the sulphuret of ammonia, nor solutions of oxyd of arsenic or corrosive muriat of mercury occasion any precipitate; the latter substance however changes the colour of the solution to yellow. With sulphat of iron there is formed a brown precipitate, which by digestion in muriatic acid is decomposed, the oxyd of iron being taken up, and yellow oxyd of tungsten remaining behind. Tincture of galls, when mixed with tunstat of soda, occasions an abundant flocculent precipitate straw of a pale colour.

Ammonia combines readily with the yellow oxyd, forming *tunstat of ammonia*; which crystallizes from its solution, by evaporation and cooling, in the form of shining plates like boracic acid, or in slender tetrahedral prisms. Its colour is very pale yellowish brown. It has a metallic taste, is soluble in water, is not deliquescent, and exhibits with the various reagents analogous properties to those of the preceding salts. By a red heat the ammonia is totally decomposed; leaving the tungsten behind in the state of yellow or blue oxyd, according as the process has been performed in an open crucible or in a retort.

The only use that has hitherto been suggested of tungsten in any form, is as a mordant. The triple acidulous tunstat when digested, according to Morveau,[h] with the red juices of fruits, and with infusions of turmeric and tournesol, forms with them coloured lakes of remarkable fixity, and hence may be of considerable use in the arts. These experiments, however, on repetition in this country, have not been attended with the success that would naturally be expected from the representations in the memoir referred to.

TURBITH MINERAL. See MERCURY.

TURF. See PEAT.

TURMERIC. *Terra Merita.* (*Curcuma longa*, Linn.)

The root of the turmeric, which is cultivated largely in the East Indies, consists of a large oval bulb, from which spring two or three tortuous processes three or four inches long. This root is of a dusky brown externally, and of a deep orange yellow within, of a somewhat fragrant smell, and a bitterish aromatic taste. The yellow colour is extracted easily, both by water and alcohol, and is sometimes used in dyeing, but the dye is extremely fugitive, and cannot be fixed on cloth by any known mordant, which is a loss to the dyer as there is no vegetable substance that gives such a rich orange yellow. When employed in dyeing it is chiefly to give a finishing gloss to the more solid colours, which soon fades. The yellow of tumeric is rendered somewhat paler by acids, but is changed to a brick-red by the alkalies and alkaline earths, and it is the latter property that renders it of use to the chemist, as its sensibility to alkaline tests is so great as to indicate a smaller quantity of these substances than can be done by any other method, and hence the exact point of saturation may be hit, which is of importance in many experiments of research. To apply it, either a spirituous tincture or a watery infusion may be used, or more simply, a fresh-cut surface of the entire root may be wetted with distilled water, and by being rubbed on white paper, a very visible yellow mark will be made, on which a drop of the liquor to be

[h] An. de Chim. vol. xxx. p. 123.

examined may be dropped. When the quantity of alkali is very small, it requires a few minutes to produce the full change.

Tumeric is used largely in the East as a condiment to food, and in particular, it is the substance that gives the colour to curry.

TURNSOLE. See Litmus.

TURPENTINE, *and other resinous products of the Pine*.

Under this head we shall describe the methods of procuring and preparing a variety of very important articles[a] of commerce, such as turpentine, resin, pitch, tar, &c. which are employed so extensively in ship-building and rigging, in varnishes, and many other purposes of inferior interest.

All these are the products of one or other species of pine, and sometimes the same substance is yielded by different species, as all the varieties of the native resin, or turpentine, have a very great resemblance in chemical properties.

There are three varieties of pine turpentine, commonly known under that name in Europe; namely, 1st. *the common turpentine*, obtained chiefly from the *Pinus Sylvestris* (Scotch Fir). 2d. *the Strasburgh turpentine* yielded by the *Pinus Picea* (Silver Fir) and 3d. the *Venice turpentine* procured from the *Pinus Larix* (Larch). To these may be added two liquid turpentines. 4th. *the Carpathian or Hungary Balsam*, which exsudes from the *Pinus Cembra* (Siberian Stone Pine). 5th. *the Canada Balsam*, the resinous juice of the *Pinus Balsamea* (Balm of Gilead Fir). The fine fragrant *Chio turpentine* is not procured from a pine, but from a low shrub (the *Pistacia Lentiscus*) which will be described in the next article.

Of the three first-mentioned turpentines, the *Venice* is the thinnest and most aromatic, the *Strasburg* the next in these qualities, and the *Common* is the firmest and coarsest. The two former are often adulterated by a mixture of the common turpentine and oil of turpentine, and it is to be observed that the terms Venice and Strasburg turpentine are not now appropriate, as they are procured from various countries.

Common turpentine is obtained largely in the pine forests in the south of France, in Switzerland, in the countries on the north of the Pyrenees, in Germany, and in many of the southern states of North America. The greater part of what is consumed in this country is imported from North America. The method of obtaining it is by making a series of incisions through the bark of the tree, from which the turpentine exsudes, and falls down into holes or other receptacles at the foot. The process is described very accurately by Duhamel and Moringlane as practised in the south of France.

The fir is generally allowed to remain untouched till it is thirty or forty years old. When it is to be worked, which is early in the spring, a small hole is first made in the ground at the foot of the tree, the earth of which is well rammed, and serves as a receptacle for the juice. The coarse bark is then stripped off from the tree, a little above the hole down to the smooth inner bark, after which a portion of the inner bark together with a little of the wood is cut out with a very sharp tool, so that there may be a wound in the tree about three inches square, and an inch deep. Immediately afterwards the turpentine begins to exsude in very transparent drops, which escape chiefly from the wood immediately under the inner bark. The hotter the weather is, the greater is the supply of resin, and to facilitate the supply the incisions are enlarged every three or four days by cutting off thin slices, till at the end of the year it is about a foot and a half wide and two or three inches deep. The whole time during which the turpentine flows is from the end of February to October. In the winter it entirely ceases, but in the ensuing spring a fresh incision is begun a little above the former, and managed in the same manner. This practice is continued annually for about twelve or fifteen years in some parts, and in others a shorter time, on the same side of the tree, till the later incisions are so high as to be out of reach without the assistance of steps; after which the contrary side of the tree is begun upon, and worked in a similar manner for as many years, during which time the first incisions are grown up, and are fit to be cut afresh. In this way, a healthy tree in a favourable soil, may be made to yield from six to twelve or more pounds of turpentine annually, sometimes for a century, and even the timber is not soon injured by this constant drain.

The flow of turpentine discontinues altogether about October, and the liquid resin collected during the year from each tree, is put together for further purification. But a considerable quantity of the resin has concreted during that time around the incision, particularly as the heat declines; and in the winter when it

[a] Dr. Matons Supplement to Lambert on the Genus Pinus. Moringlane in the Journ. de Phys. tom. 31. Murray's Apparatus Medicam. Dict. d'Hist. Nat. Article Goudron, &c. &c.

has hardened confiderably it is fcraped off, and forms what is technically called *Barras*, or in fome provinces *Galipot*, which differs from the more liquid turpentine in confiftence, and probably contains a lefs proportion of effential oil. The galipot is much ufed in making flambeaux when mixed with fuet, but the greater part of it, as well as the liquid turpentine, is fubjected to further proceffes.

Thefe we fhall refume when we have defcribed the method of obtaining the other kinds of turpentine, which however, is fo very fimilar that a few words will fuffice.

The *Strafburgh Turpentine*, the produce of the filver fir, is the moft fragrant of all the pine turpentines, and only inferior to the true Chio, but it is not often feen in the fhops. It is obtained by rude incifion of the bark by the peafants in the vaft pine forefts on the weftern Alps. The firft cut is made as high as the hatchet will reach, and thefe are renewed annually from above downwards to within a foot of the ground. But the fineft kind of turpentine yielded by this tree, is that which exfudes from foft tubercles or fwellings of the inner bark. The peafants carry with them a large cow's horn, with the point of which they pierce thefe tubercles, and collect the juice in its hollow. Only a few drops are yielded from each tubercle, fo that this turpentine is rare and bears a higher price. It is called technically *Bigoin* or *Oil of Pine*, and when thickened by expofure to the air, it remains clear like maftich, whereas the turpentine obtained from the fame tree by incifion of the bark becomes white and opake by age.

The true *Venice turpentine*, or refin of the Larch, is obtained from the Tyrol and Savoy, and alfo from Dauphiny, by boring holes about an inch in diameter, with a gentle defcent, in the moft knotty parts of the tree. To thefe are adapted long perforated pegs, which ferve as gutters to convey the juice into troughs placed beneath. It is yielded during the whole of the fummer, and is fimply purified by ftraining through hair fieves. A full-grown larch will fometimes yield feven or eight pounds of turpentine annually for forty or fifty years.

Much of the Venice turpentine of the fhops is brought from America, and it is doubtful from what tree it is procured. This turpentine hardly becomes folid by any length of keeping.

The Carpathian, or Hungary Balfam, is obtained from the Stone Pine in Hungary and the Tyrol, either by breaking off the twigs of the tree, and collecting in a glafs the fine refin that exfudes; or by boiling the ends of the frefh boughs in water, when the balfam rifes to the top. The former method yields by far the beft. This is a whitifh, pellucid, and very fluid turpentine, which does not harden by keeping.

The Canada Balfam is a tranfparent whitifh juice, of the confiftence of Copaiva balfam, and of a very fragrant fmell and bitterifh tafte, obtained from the Balm of Gilead Fir, and imported from Canada, but the mode of collection is not well known.

To return to the various operations performed upon the common turpentine, which as above mentioned is obtained in two degrees of liquidity, the moft fluid being called properly turpentine, and the leaft fluid having the name of *barras* or *galipot* in the South of France, whence it is procured.

The turpentine contains a number of impurities entangled in its fubftance, from which it is purified in two methods. One of them is to inclofe it in a cafk perforated at bottom, and by expofure to a hot fun it becomes fo fluid as to filter through, which gives the fineft and moft valued turpentine. The other method is to heat it moderately in a large copper, till it is quite liquid, and then to filter it through a ftrainer made of rows of ftraws laid clofe to each other. This gives it a golden colour.

The harder turpentine, or *Barras*, is alfo purified in the latter mode, but inftead of being merely liquefied in the copper, the heat is continued for fome time, till part of the effential oil is fo far diffipated that a little of it cooled on a piece of wood may be crufhed to powder by the fingers. It is then ftrained through ftraw while hot, and the pure refin on cooling hardens into a yellow opake mafs which is called *Brai-fec* or *Rafe*. This is fometimes fold as *Burgundy pitch*, which however appears to be properly the product of another fpecies of pine, as we fhall prefently mention. This opake yellow brown refin is rendered tranfparent, and of a fine clear amber yellow, by mixing it when melted with about an eighth of boiling water, and ftirring it inceffantly for a confiderable time till the water is cold. The refin is then caft into moulds and cooled.

Effential Oil of Turpentine. This valuable oil is prepared largely, both in the countries where the turpentine is extracted, and from turpentine imported into this country. The procefs is the following: an alembic with a worm and cooler, is ufed, precifely of the fame conftruction as

what is employed for the diſtillation of ſpirits; this is filled with turpentine and water in due proportions, and the volatile part after diſtillation is found to conſiſt of oil of turpentine ſwimming on water. This oil is perfectly limpid and colourleſs, has a very ſtrong ſmell, a bitteriſh taſte, is extremely inflammable, and in ſhort poſſeſſes all the properties of the other eſſential oils. It is employed in immenſe quantities in a variety of varniſhes and ſimilar preparations, but for the finer purpoſes ſuch (for example) as that of diſſolving gum copal, it is neceſſary to rectify it by a ſecond diſtillation with water in a ſtill, uſing a very gentle heat, and keeping apart the firſt product which is the beſt. From 250 lbs. of good turpentine about 60 lbs. of oil may be obtained.

Common Roſin. Yellow Roſin. Colophony. The reſidue from the diſtillation of the oil of turpentine, is an opake, brittle, light yellow maſs, much leſs clammy and coheſive than inſpiſſated turpentine, and requiring a greater heat for fuſion: it is the common reſin or roſin of the ſhops. It is alſo called by the French *Brai-ſec*, as well as the boiled *galipot* or harder turpentine, but the latter is more eſteemed as it ſtill contains a good deal of eſſential oil, and is fitter for moſt of the purpoſes for which the terebinthinate ſubſtances are employed. When common roſin is boiled with water for a time, it becomes yellow and tranſparent, and is then the roſin uſed by muſicians to rub the bows and ſtrings of violins. When common roſin is kept in fuſion for a conſiderable time, it becomes of a browner colour, is ſtill harder and leſs adheſive to the fingers when cold, and is then called *Black Roſin* or *Colophony*, and this is the ultimate point to which the inſpiſſation of turpentine is carried.

There are other leſs important varieties in the products of common turpentine, which it is needleſs to deſcribe.

A very fine eſſential oil is prepared in ſome parts of Germany, by diſtillation of the green tops and cones of the Stone Pine (*Pinus Cembra*) which is known in medicine by the name of *Oleum Templinum*, or popularly, *Krumholzoel*, and is an approved remedy for a number of complaints. It is ſomewhat greeniſh, or ſometimes of a golden yellow, very fragrant and aromatic.

The true *Burgundy Pitch* is a brittle opake light-yellow or ſometimes reddiſh-brown reſin, of a fine terebinthinate ſmell and taſte, which is chiefly imported from Saxony, and is collected in quantity in the neighbourhood of Neufchatel from the Norway Spruce Fir.

Inciſions are made in the uſual manner, and the ſurface of the wood laid bare, which is ſoon covered with a turpentine, leſs liquid than the common ſort, and which therefore ſoon concretes on the inciſion without flowing down. This is picked off, and when a ſufficient quantity is collected it is put with water into large boilers, melted, and then ſtrained under a preſs, through cloſe cloths into barrels, in which it is tranſported for ſale. Burgundy pitch is of ſuch a conſiſtence that it will barely ſoften by the heat of the human body, and is much uſed in plaſters. It is often adulterated (as is ſuppoſed) by a mixture of roſin and turpentine.

Burgundy Pitch is alſo obtained from the Larch.

The ſubſtance commonly called *Frankincenſe*, (*Thus*) is a ſolid brittle reſin in ſmall roundiſh maſſes of a browniſh yellow on the outſide, and white internally. It poſſeſſes the common properties of the turpentines, and has a very pleaſant ſmell when burned. It is ſuppoſed to exſude ſpontaneouſly (and not by inciſion) from the Norway Spruce, and to undergo no preparation.

All the terebinthinate ſubſtances above deſcribed are either nearly in the ſtate in which they exſude from the tree, or are prepared by heat with the intervention of a ſuitable apparatus.

There is another product more important than any other, eſpecially to a maritime country, which is prepared by a kind of diſtillation *per deſcenſum*, with no inconſiderable ſkill, but often without any other apparatus than the ſubſtance itſelf that yields it, and this is common *Tar*.

Tar.—Goudron, *Fr.* is a thick dark brown or black reſinous adheſive juice melted by fire from the wood and roots of old pines and fir trees, during which proceſs the wood itſelf is reduced to charcoal.

Every part of the tree which is at all reſinous is fit for obtaining tar, but in particular it is the red wood and the hard roots that yield the greateſt quantity and the beſt. As the wood is entirely charred in the proceſs, all the ſap and other volatile parts muſt be expelled, moſt of which mixes with the turpentine, which ſweats out and conſtitutes tar, and hence this ſubſtance muſt conſiderably vary in the quality

and proportion of resin, empyreumatic oil and acid which it contains, according to the age of the tree, the soil on which it grows, the part selected, the management of the heat, &c.

The extraction of tar from pine-trees is very antient, being described by Theophrastus, Dioscorides, and other old authors, and the method of proceeding was extremely simple. Very large stacks were made of billets of pine and covered with turf to prevent the volatile parts from being dissipated. They were then kindled and suffered to burn with a low smothered flame, during which the tar melted out by the heat, flowed to the bottom of the stack, and ran out by a small channel cut for the purpose. A very large proportion of the tar actually made in Norway, and the other Baltic countries, is prepared in this rude manner. The stacks are built upon the slope of a hill, covered with moss and turf, kindled, and the tar that oozes out is collected and put into barrels.

But a more economical and scientific method is practised in France and Switzerland, which is to heat the wood in large brick ovens built for the purpose, whereby the wood is charred much more equally, and the tar is of a more uniform, and probably a better quality. The following is the method of proceeding in the Valais: the pines are previously felled in the preceding year that the wood may be dry enough when wanted, and the outer bark and twigs being stripped off, the rest of the tree is cut up into billets of tolerably equal size. The oven is built of stone or brick in the form of an egg standing on its small end. The floor is made either of a single stone scooped out into a hollow, or of several joined very accurately. On one side of it, about five inches above the lowest part, is a hole in which a large gun-barrel is thrust, which serves to convey off the liquid tar as it collects. A large iron grate is laid at the bottom of the oven. The largest of these ovens are about ten feet high, and five or six feet in the largest diameter. To charge the oven, bundles of these billets are thrown in, and the wood spread as evenly as possible, filling the interstices with the chips, till it nearly reaches the top. The whole is then covered with a layer of chips, and the top of the furnace is closed with flat stones heaped one upon the other, gradually lessening the opening, and forming a kind of vaulted chimney, the mouth of which is four or five inches across. The dry chips at top of the furnace are then set on fire, and the heat spreads downwards till the whole of the charge is judged to be sufficiently kindled. The chimney is then entirely closed with a large stone, and wet earth is heaped on the stones at top, and thrown on wherever the smoke bursts out too strongly. The melting now begins, the tar falls down to the bottom, fills the hollow of the floor (which last detains any bits of wood and other impurities) and runs off through the gun-barrel into casks placed to receive it. Some skill is required in managing the fire, which must sometimes be refreshed by letting in a small draught of air through small holes left for the purpose in the sides of the kiln. When the process is over, the wood is found compleatly charred, and is taken out, and the oven after being cleared out is again filled. It is found that the red wood and knots, which are the richest in resin, will yield about a fourth of their weight of tar, but the general average of product is about 10 or 12 per cent. of the weight of the whole charge. After each process a quantity of *lamp-black* is collected beneath the stones that form the vault of the temporary chimney.

This latter substance is also another product from the pine, and in the large way is procured by a different process, as described under the article *Carbon*.

A substance somewhat resembling tar, called *Brai-gras*, and much used in the French ports for careening ships, is made in the following way. The oven above described is charged with alternate layers of chips of green wood, and billets of dry, and all the refuse matter of turpentine, the straw through which it is strained, and the like. Over the whole is laid a stratum of *brai-sec*, or rosin, and the gun-barrel pipe is stopped up, and not tapped till the whole of the wood is reduced to charcoal. The vault of the oven is also covered more carefully after the charge is sufficiently kindled, and the whole process is carried on more slowly. The heat of the fire melts the rosin at top, which mixes with the resinous sap, and the whole collects into a dark resinous liquid at the bottom. When sufficiently cooled it is drawn off and barrelled. The *brai-gras* is of an intermediate consistence, between tar and rosin.

Pitch. The substance called Pitch in this country, is simply tar, inspissated to the requisite degree by boiling.

It does not appear, however, that the French have this precise preparation, as the substance called *Poix* is made either by melting together due proportions of rosin with tar, or else by filling a kind of oven with various refuse matters from the turpentine, such as the straw

through which it has ſtrained, together with the coarſe ſtrainings, chips of bark ſoaked in turpentine, the broken earth of the moulds in which the reſin collects, &c. kindling it till all the reſin falls down into a reſervoir, and continuing the heat till it is ſufficiently inſpiſſated. This forms a hard black maſs called *Poix dure* or *Pegle*.

The pitch made in this country by boiling down tar to the proper conſiſtence, is now performed near London, and in ſome other parts, in a ſtill with a worm-tub attached to it, in order to collect the valuable volatile products of the tar. The proceſs is the following:[b] the barrels of tar being of various conſiſtence, their contents are firſt emptied into a copper, and gently heated and well ſtirred, to render them thin and uniform. The tar is then laded into the ſtill, paſſing through a ſieve to keep out chips of wood and other impurities.

When the ſtill is properly luted, the fire is kindled and kept up very moderate for three hours, as the tar is very apt to boil up in the early part of the proceſs. The firſt product that diſtills over is principally a brown acid water, mixed however with a good deal of oil. As the proceſs advances, and the heat is increaſed, the quantity of acid leſſens, and that of oil increaſes, and towards the end of the diſtillation the product is chiefly oil. The length of the proceſs varies according to the quality and hardneſs of the pitch required. In general a ſtill that holds about 600 gallons will work 18 or 20 barrels of tar in 8 hours, the produce of which will be about 10 barrels of pitch (or 22 cwt.), 176 gallons of oil; and about 40 gallons of acid. The pitch remains in the ſtill for 12 hours, after which it is barrelled, and hardens as it cools.

The oil and acid water which diſtill over do not mix, ſo that they may be eaſily ſeparated by decantation. The oil is a browniſh inferior kind of oil of turpentine, which is very uſeful in painting ſhips and other coarſe out-door work. The acid is a very ſtrong browniſh empyreumatic acid, which appears very cloſely to reſemble the pyroligneous acid obtained from the diſtillation of wood during its converſion to charcoal, and is now employed pretty largely in compoſing ſeveral of the mordants in callico printing.

TURPENTINE (*Chio.*)

This is a very fragrant reſin, obtained ſparingly by inciſion of the bark of the *Piſtacia Terebinthus*, a ſmall tree growing in the Iſle of Chio, and in many other parts of the Levant.

It is a thick and tenacious ſubſtance, whitiſh, nearly tranſparent, highly fragrant, and almoſt taſteleſs. It is ſeldom found genuine, the common Chio turpentine of the ſhops being largely adulterated with the finer ſorts of the pine turpentines.

TURQUOISE.

The colour of this ſubſtance is pale ſky-blue, paſſing into indigo-blue and pale apple green. It occurs in maſs or diſſeminated. Its fracture is even. Its hardneſs is nearly equal to that of glaſs; it is difficultly frangible. Sp. gr. 3.12.

Before the blowpipe its colour changes to greyiſh white, and it becomes friable, but does not melt. It is ſoluble in nitro-muriatic acid, and the European varieties are ſo in nitric acid; this menſtruum however has no action on the Perſian turquoiſes. It is compoſed, according to Buillon La Grange, of

80	Phoſphat of lime
8	Carbonat of lime
2	Phoſphat of iron, with a trace of mangeneſe
2	Phoſphat of magneſia
1	Alumine
6	Water and loſs
99	

Turquoiſe is generally conſidered as foſſil bone, or ivory penetrated by oxyd of copper; it appears, however, from the above analyſis, that the colouring matter is phoſphat of iron. The oriental turquoiſes are found near Meched in Perſia, alſo in Mount Caucaſus, in Egypt and Arabia. The occidental ones are found in Languedoc in France, and in Hungary. Turquoiſe was formerly in ſome eſtimation for rings and other articles of perſonal ornament, but its value has greatly declined in modern times. The colour of turquoiſe changes gradually by expoſure to the air, from blue to green: when it arrives at this ſtate its commercial value is wholly extinct.

TUTENAG. See COPPER, alloys of.

[b] Original Communication.

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ULTRAMARINE. *Outremére.* Fr.

This precious colour ſo remarkable for its beauty and durability is a pure deep ſky blue. It is capable of bearing a low red heat without injury, and it is not ſenſibly impaired by the action of the air and weather. It is the colouring matter of the mineral already deſcribed under the name Lapis Lazuli, and appears according to an analyſis by Klaproth, to conſiſt of little elſe than oxyd of iron. The method in which this pigment is ſeparated from the earthy parts of the above mineral is as follows. Let the lapis lazuli be heated juſt to redneſs, and then ſuddenly quenched in cold water, and let this be repeated two or three times till the ſtone becomes almoſt friable; then let it be ground down with a few drops of water in a clean iron mortar, or ſtill better, in an agate one till it is reduced to a perfectly impalpable powder. Then take one pint of linſeed oil, warm it over the fire in a clean veſſel, and add one pound of bees-wax, one pound of turpentine, half a pound of roſin, and half a pound of gum maſtich: keep the ingredients over the fire, with conſtant ſtirring till they are melted and thoroughly incorporated together; the reſult will be a tenacious adheſive maſs. Of this take any quantity, 6 oz. for example, melt it and pour it into a warm clean mortar; then ſprinkle upon it 3 oz. of pulverized lapis lazuli, and incorporate it thoroughly by long beating with the peſtle; this being done pour in ſome warm water, and again work it about in the ſame manner as before: in a ſhort time the water will become charged with the blue colouring matter; it muſt then be poured into a clean tall glaſs, and replaced by freſh, proceeding in this manner till the paſte will give out no more colour on the addition of freſh water. By ſtanding a few days the colour will ſubſide from the water in which it was ſuſpended; the clear fluid being then decanted off, and the reſt got rid of by evaporation, there will remain a deep-blue powder which is ultramarine.

UMBER.

There are two kinds of umber, the one called *Cologne Umber*, is a variety of peat or of earthy brown coal. There are large beds of it wrought in the neighbourhood of Cologne, principally as an article of fuel; a pretty conſiderable quantity is alſo imported into Holland, where it is uſed in the manufacture, or more properly in the adulteration of ſnuff, for which purpoſe it appears to be better than the common peat of the country; a ſtill ſmaller quantity is conſumed by the paint-makers.

The colour of this vegetable umber is a warm ſomewhat pinkiſh brown, and is an uſeful ingredient to the painter in water colours.

The ſecond kind of umber goes by the name of *Turkiſh umber*, and appears to be a variety of the iron ore called brown ironſtone ochre. A ſpecimen from Cyprus was analyſed by Klaproth,* and afforded him,

48	Oxyd of iron
20	Oxyd of manganeſe
13	Silex
5	Alumine
14	Water
100	

URANIUM.

Uranium is a brittle hard metal, of extremely difficult fuſibility. It is ſoluble in nitro-muriatic acid, and is precipitable from its ſolution of a yellow colour by cauſtic alkali, and of a browniſh-red by pruſſiated potaſh.

§ 1. *Ores.*

Sp. 1. Black Uranium. *Pecherz*, Wern. *Pechblende*, Widenm, &c.

Its colour is velvet black paſſing into iron-grey and browniſh black; it is ſometimes ſuperficially tarniſhed like tempered ſteel. It occurs in maſs, diſſeminated, and in ſmall reniform pieces. Internally it has uſually a gliſtening ſemi-metallic luſtre; its fracture is imperfectly conchoidal, paſſing into granular uneven. It ſometimes occurs in thick lamellar or granular diſtinct concretions. It is moderately hard, paſſing to ſoft, is brittle and eaſily frangible. Sp. gr. = 7.5.

It is infuſible *per ſe* before the blowpipe; with ſoda or borax it forms a dull greyiſh ſlag, and with the alkaline phoſphats a clear green glaſs. It is ſoluble in nitric acid, giving out abundance of nitrous gas.

A ſpecimen from Bohemia was analyſed by Klaproth, (to whom the diſcovery of the new metal which it contains is owing) with the following reſult.

* Analyt. Eſſ. vol. ii. p. 106.

86.5	Uranium in the ſtate of ſub-oxyd
2.5	Black oxyd of iron
6.	Sulphuret of lead
5.	Silex
100.0	

Of theſe ingredients the two laſt appear to be only caſual, for in an analyſis by Lampadius, of a ſpecimen of this mineral from Saxony, there were obtained only uranium and iron; in another there was a ſlight admixture of copper pyrites.

It occurs in veins in primitive mountains, mixed with ores of lead and ſilver, with copper pyrites, iron ochre, and cobalt. It is found at Joachimſthal in Bohemia; Johanngeorgenſtadt, in Saxony; and Kongſberg in Norway.

It is diſtinguiſhable from blende, with which it was formerly confounded, by its ſpecific gravity, and fracture, as well as chemical characters.

Sp. 2. Micaceous Uranium. *Uran-glimmer*, Wern. *Urane micacé*, Broch.

Its uſual colour is graſs green of more or leſs intenſity, whence it paſſes on one hand to greeniſh ſilvery white, and on the other to ſulphur yellow. It occurs ſometimes as a ſuperficial cruſt but more uſually cryſtallized in the form of rectangular tables; theſe tables are ſometimes ſo thick in proportion to their other dimenſions as to approach to the cube, and ſometimes two oppoſite terminal planes are ſo deeply bevilled on all their edges as to give the entire cryſtal the appearance of a truncated octohedron; the cryſtals are generally very ſmall, and cellularly aggregated; the terminal planes are ſtriated, the lateral ones are ſmooth; the external luſtre is more or leſs ſhining; the internal is gliſtening and pearly; the fracture is ſtrait foliated in a ſingle direction. It is tranſlucent, ſoft, not brittle, but eaſily frangible. Sp. gr. 3.12.

It is ſoluble in nitric acid without effervesſcence, and communicates to it a yellow colour. The yellow variety of this mineral appears from an aſſay by Klaproth, to be pure oxyd of uranium; the green varieties contain a little oxyd of copper, to which that colour is owing.

It occurs in veins of ironſtone in primitive mountains, accompanied by the other ores of this metal, and ſometimes by cobalt, and arſeniat of copper. It is found at Carrarach in Cornwall, Eibenſtock in Saxony, Saſka in the Bannat, and St. Symphorien near Autun in France.

Sp. 3. Ochery Uranium. *Uranokker*, Wern. *Ocre d'Urane*. Broch.

Its colour is ſtraw-yellow paſſing into orange and greeniſh yellow. It occurs ſuperficial, diſſeminated, and maſſive; it is dull or ſlightly glimmering; its fracture is earthy paſſing into ſmall and imperfectly conchoidal. It is opake, ſoft, ſometimes even friable; is brittle and meagre to the touch. Sp. gr. = 3.2.

The yellow varieties, according to Klaproth, are pure oxyd of uranium, the orange coloured contain a ſmall admixture of iron.

It occurs with the other ores of uranium.

§. 2. *Aſſay and Analyſis.*

The analyſis of the ores of uranium is ſufficiently ſimple. The only ſubſtances that have hitherto been found in natural mixture or combination with this metal, are lead, iron, copper, ſulphur, and ſilex, which may all be ſeparated in the following manner:[b]

a. Let the ore be digeſted with moderately dilute nitric acid, by which the greater part of it will be taken up; the reſidue being waſhed and dried is to be gently ignited, by which the *ſulphur* will be burnt off; what remains after ignition is to be digeſted with dilute nitric acid, and the inſoluble portion is *ſilex*.

b. To the nitric ſolutions and waſhings mixed together, is to be added ſulphat of ſoda as long as any precipitate falls down; this when collected on a filter, waſhed and dried, is ſulphat of *lead*.

c. The remaining ſolution is to be totally decompoſed by cauſtic fixed alkali, at a boiling heat, and the powder thus obtained is to be digeſted in cauſtic liquid ammonia till the whole of the copper is taken up. The ammoniacal ſolution being then ſlightly ſuperſaturated by ſulphuric acid, the *copper* may be obtained either in the metallic ſtate by means of a bar of iron or zinc, or in the ſtate of brown oxyd, by boiling with cauſtic fixed alkali.

d. The reſidue of the precipitate *c.* after extraction of the copper, is to be evaporated to dryneſs two or three times with nitric acid, and is then to be gently digeſted in dilute nitric acid, which will take up the uranium, leaving the iron behind in the ſtate of per-oxyd.

e. The nitrat of uranium being boiled with cauſtic fixed alkali the whole of the uranium is precipitated as pure yellow oxyd.

[a] Klapr. Analyt. Eſſ. vol. i. p. 476.

§ 3. *Chemical and Physical Properties.*

The method of obtaining reguline uranium, according to Klaproth, though simple, is not very easy, on account of the high heat required for this purpose; it being greater than that necessary for the reduction of oxyd of manganese; 50 grs. of the pure yellow oxyd being made up into a ball with wax were placed in a close crucible lined with charcoal, and exposed for some hours to the most intense heat of the Berlin porcelain furnace, equal to 170° Wedg. There was thus obtained a metallic button weighing 28 grs. of an iron-grey colour and metallic lustre, composed of hard minute grains, firmly adhering to each other. Its sp. gr. was = 8.1. Other attempts to reduce the yellow oxyd by the assistance of borax and other saline fluxes entirely failed; the result being only a black vitreous scoria.

Uranium is soluble with effervescence in nitric acid, nitrous gas being at the same time given out, but the other simple acids appear to have little or no action on it, neither does it appear to be affected by the alkalies. It is not easily oxydized by exposure to air and heat, at least no change is produced in it by the blow-pipe on charcoal.

Uranium appears capable of two states of oxydation; the method of procuring the yellow or per-oxyd, we have already mentioned in the preceding section. The black or sub-oxyd may be procured by mixing the yellow oxyd with oil, and then gently burning it off on a test; from 120 grs. of yellow oxyd treated thus, Klaproth procured 85 grs. of black oxyd. This latter differs from the former, not only in colour, but in its producing nitrous gas when digested with nitric acid. The relative composition of the two oxyds, as deduced from the above facts, is,

56 metal + 44 oxygen = 100 of yellow oxyd,
79.9 metal + 20.1 oxygen = 100 of black oxyd.

The yellow oxyd is readily soluble in acids. When digested with diluted sulphuric acid it readily dissolves, and by evaporation and cooling deposits sulphat of uranium in the form of small prisms of a lemon yellow colour. Dilute nitric acid dissolves the oxyd of uranium with facility, and the salt hence resulting crystallizes in oblong hexagonal tables of a light green colour. Muriatic acid in like manner takes up this oxyd and crystallizes in the form of rhomboidal tables, of a greenish yellow colour. Concentrated distilled vinegar takes up the oxyd of uranium by digestion, and forms clear topaz-yellow crystals in the form of tetrahedral prisms terminated by tetrahedral pyramids; when these crystals are very slowly ignited, the acid is driven off, and nothing but the oxyd remains, without the form of the crystals being injured. Phosphoric acid is capable also of dissolving this oxyd but the solution in a short time becomes turbid from the precipitation of a flocculent sub-phosphat of a yellowish white colour.

All the above solutions are decomposable by caustic alkali, a lemon yellow oxyd being thrown down. Carbonated alkali throws down a yellowish white precipitate which is partly resoluble in an excess of mild alkali. Prussiat of potash throws down from these solutions a copious brownish red precipitate resembling kermes mineral. Hydrosulphuret of ammonia occasions a brownish yellow precipitate; and tincture or infusion of galls a copious chocolate brown one.

The affinity of this oxyd for the acids is so considerable that its salts are not decomposed by the addition of zinc or of any other metal.

The following vitrescent mixtures were made by Klaproth, to ascertain the power of this oxyd as a colouring substance.

Silex — — — 2 drachms
Carb. potash — — 1 drachm
Yellow oxyd — — 10 grs.
produced a clear light brown glass.

Silex — — — 2 drachms
Carb. soda — — 1 drachm
Yellow oxyd — — 10 grs.
produced an opake blackish grey glass.

Silex — — — 2 drachms
Glass of borax — — 2 drachms
Yellow oxyd — — 20 grs.
produced a clear glass of a smoke-brown colour.

Silex — — — 2 drachms
Vitreous phosphoric acid (from bones) — 2 drachms
Yellow oxyd — — 20 grs.
produced an opake apple-green glass, like chrysoprase

Vitreous phosphoric acid 2 drachms
Yellow oxyd — — 10 grs.
produced a clear emerald-green glass.

The glass produced by the two latter experiments was however in some degree deliquescent.

The yellow oxyd when mixed with the common enamelling flux, tinges porcelain of a deep orange yellow.

The alloys of uranium are as yet wholly unknown.

UREA. See URINE.

URIC, or LITHIC ACID. See URINARY CALCULUS.

URINARY CALCULUS.

In the bladder of many animals, and particularly of man, hard round concretions, stony in appearance, are frequently formed, which produce most dreadful paroxysms of pain and general disease, for which no radical cure has hitherto been discovered, except a very serious surgical operation.

The stone of the bladder has been examined with extreme attention by several most excellent chemists, who have been stimulated by the additional hope of finding a solvent which might remove it altogether, or at least mitigate the severity of the symptoms which it produces, and it was early discovered that a considerable benefit was derived from the internal use of alkaline medicines, taken in as large quantity as could be borne, and for a length of time.

The first and by far the most important discovery relating to the chemical nature of calculus, was made by Scheele, in 1776,[a] who obtained from it a large proportion of a peculiar crystallizable substance till then unknown, which had all the properties of a very weak acid, particularly in reddening litmus, and neutralizing alkaline and earthy bases. This substance was afterwards denominated the *Lithic Acid*, and more lately the Uric Acid. This discovery gave a new interest to the examination of calculi, and many additional observations have been added by other chemists. Bergman, who was employed on the same subject at the same time with Scheele, gave some further remarks on its habitude with acids. Dr. Wollaston[b] has shewn that the gouty calculus, or *chalk stone*, as it is generally called, consists of the lithic acid neutralized by soda, and has also added largely to our knowledge of the varieties of urinary calculi, by discovering that phosphat of ammonia and magnesia is the composition of one species; that pure phosphat of lime forms another species; and that the variety known to surgeons by the name of the mulberry calculus, consists of phosphat and oxalat of lime.[c] Dr. Pearson in analysing 200 specimens of calculi, has found the lithic acid of Scheele in all but six, in very various proportions, but he considers this peculiar substance rather as an animal oxyd than an acid. Brugnatelli and other chemists whom it is needless to enumerate, have thrown some further light on this subject; and lastly, a long and most elaborate series of experiments has been made by Messrs. Fourcroy and Vauquelin, which gives the fullest and most comprehensive view of the subject.[d]

From all these authorities we may collect the following particulars:

The greater number of urinary calculi or stones of the bladder, are of a round or oval shape, varying in size from that of a bean to the bigness of a pullet's egg; brittle, hard enough to take a good polish; when sawn through obviously composed of concentric laminæ formed round a small nucleus; of a dull yellow to a red gravelly colour, often interspersed with blood-red spots; and the specific gravity of even the heaviest, does not quite amount to 2. These are the calculi in which the lithic or uric acid enters as a constituent part, but even in these there is a considerable variety of texture and appearance, the surface being sometimes smooth and polished, sometimes rough, with small protuberances, and occasionally interspersed with crystals, which latter are the ammoniaco-magnesian phosphat.

The *mulberry calculi*, as they are called, are distinguished by their mamillated, and usually polished surface, resembling that of the mulberry, and their colour too is generally much darker. These, as before mentioned, have been found by Dr. Wollaston to consist chiefly of oxalat of lime. The analysis of this and of the other rarer varieties, will be mentioned after we have described the common lithic calculus, which is particularly distinguished by its lamellar texture, its toughness, and the uniform brown yellow colour of the inner part, a good deal resembling petrified wood in appearance.

When this calculus is boiled for some time in water, a solution is obtained holding about 8 grains in 5 oz. of liquid, which reddens litmus paper.[e] As it grows cold the greatest part of the dissolved portion of calculus separates again in the form of fine crystals, which are the pure *Lithic* or *Uric* acid. The muriatic acid has no effect on this calculus. Concentrated sulphuric acid dissolves it by the assistance of heat. But the most characteristic effects are those produced by the nitric acid. When this acid, somewhat dilute, is boiled on the calculus, the latter is entirely dissolved, red vapours arise, and a good deal of carbonic acid gas is produced.

[a] Essays. [b] Phil. Trans. for 1797. [c] Ibid. for 1798. [d] Systemé de Conn. Chem. tom. 10. [e] Scheele.

The solution is acid, though more of the calculus is added than the nitric acid can dissolve; it is of an orange-yellow colour, which reddens by evaporation, and produces rose-coloured spots on the skin about half an hour after it has been applied. This solution is not precipitated by any caustic alkali, but when an excess of it is added, an alkaline solution is produced, which is of a rose-colour when heated, and tinges the skin equally with the acid solution.

Lime water decomposes the solution, and gives a white precipitate, which however is not uric acid or urat of lime, but oxalat of lime, owing to the production of some oxalic acid by the action of the nitric acid. This is confirmed by the more compleat action of the oxymuriatic acid,[f] for when a lithic calculus is digested on this liquid, or, still more readily, when this acid gas is passed through water, holding the calculus suspended in fine powder, the colour of the latter grows paler, it swells, softens, becomes gelatinous in appearance, and dissolves almost entirely with the gentle evolution of bubbles of carbonic acid gas. The uric acid is now entirely lost, and the solution contains muriatic acid, ammonia, and the oxalic and malic acids. Of these, the two latter substances are entirely generated from the uric acid, by means of the oxymuriatic, and the ammonia is either totally produced by the same means, or partially, when the calculus previously contained a small portion of this alkali, which is sometimes the case. But there can be no doubt that part of the volatile alkali that appears, is actually produced in this instance, since the pure uric acid will yield it by fire in cases when none of it appears in treatment with the fixed alkalies.

When this calculus is boiled with the carbonated alkalies, little if any effect is produced, but the caustic fixed alkalies dissolve it readily, even in the cold, when there is an excess of the alkali. This solution is yellow, tastes sweetish, and alkaline, but when neutralized, the alkaline urat crystallizes. Liquid ammonia also dissolves the calculus, though with difficulty. Lime-water has the same effect, and the caustic taste of the lime disappears. In all these cases a true neutral salt is produced of the uric acid and the alkali or alkaline earth employed, which is soluble in water. These solutions are decomposed by every acid, even the carbonic, so that the uric acid has an extremely weak affinity with the several bases. These decompositions too are much assisted by the extremely sparing solubility of the uric acid alone, so that as soon as any other acid is added to the urat, the uric acid is deposited in small, brilliant, bulky, needled crystals, of a faint yellow or wood colour. This is the most convenient method of procuring this acid for examination, namely, by digesting the uric calculi in hot caustic potash or soda, and then separating it by muriatic acid. Carbonat of ammonia will also separate the uric acid from its alkaline solutions, owing no doubt to the simple agency of the carbonic acid which this salt contains in such abundance, its ammonia being volatilized in the process.

When a portion of this calculus is heated *per se* in a retort, an ammoniacal watery liquor rises, but no oil. This is accompanied by a brown sublimate, which may be whitened by a second sublimation, and is then without smell, has a sourish taste, is easily soluble in boiling water, and is somewhat different from the uric acid formed by precipitation of the alkaline solution. A good deal of carbonic acid is given out during the heating of the calculus, and a strong fetid smell like burnt horn is perceived, together with an odour like peach-flowers, which indicates Prussic acid.

The uric acid is contained in small quantity in the most healthy urine,[g] for if some of this liquid is evaporated it deposits a fine red powder, which is soluble in alkali, and has all the properties of urinary calculus. The red sediment which settles from the urine of persons after an ague fit, is of the same nature.

The uric acid therefore, though it has many properties similar to the benzoic, and others resembling the succinic, must at present be considered as a distinct acid, which occurs only in urine and in most kinds of urinary calculi, and is distinguished by its sparing solubility in water, by its separation in a crystalline form from its alkaline solution by every acid, by its solubility in nitric acid, and the rose-coloured tinge with which it stains the skin, by the acid sublimate and the ammonia which it gives when sublimed, and the very small quantity of animal oil which is produced under the action of fire.

Urat of ammonia is often found in urinary calculi. The presence of ammonia as an *educt* and not a *product*, is ascertained by the pungent ammoniacal smell which is given out when this calculus is digested with a fixed alkali. The calculi, of which it forms the principal part,[h] are generally small, coffee-coloured, arranged in thin roughish laminæ, usually with a deposition of phosphat of lime interposed, and often intermixed with ammoniaco-magnesian phosphat.

[f] Fourcroy. [g] Scheele. [h] Fourcroy.

Urat of soda has been found by Dr. Wollaston to be the composing ingredient of the gouty chalk-stones, or calculi deposited under the skin, chiefly in the neighbourhood of the joints, and which may be mentioned in this place. If a small quantity of dilute sulphuric acid is poured on the chalk-stone, part of the alkali is extracted, and crystals of Glauber's salt may be obtained from the solution. Muriatic acid, in like manner, produces common salt. The insoluble residue is the uric acid. Boiling water dissolves rather more of the chalk-stone than it would do of pure uric acid, and an urat of soda crystallizes by cooling. If lithic acid be triturated with soda and water, they unite, and a compound is formed, which, when the superfluous alkali has been washed out, very closely resembles the chalk-stone.

Phosphat of Ammonia with Magnesia.

A species of urinary calculus exists, which was first noticed by Mr. Tennant to differ from common calculi in being fusible under the blowpipe into an opake white glass, instead of being almost totally consumed; whence this able chemist conjectured it to be phosphat of lime, united with some other phosphoric salt. This conjecture was found to be almost exact, by the subsequent analysis of Dr. Wollaston, who ascertained its composition to be a triple salt, composed of phosphoric acid, ammonia, and magnesia.

This fusible calculus is always whiter and harder than the common calculi, and generally has the appearance of sparkling crystals, which are sometimes voided in the form of a white sand. The white amorphous calculus of this species contains, besides the triple ammoniaco-magnesian phosphat, some phosphat of lime and a little uric acid, but the crystals are the pure triple salt. These were analysed by Dr. Wollaston in the following manner: the ammonia was first driven off by heat, and the crystals were rendered opake. Nitric acid then dissolved the remainder, and by adding nitrat of mercury an insoluble phosphat of mercury was formed, whence the mercury was expelled by heat, and the phosphoric acid remained single. Sulphuric acid added to the supernatant liquor produced Epsom salt, shewing the presence of magnesia. These crystals require a large quantity of water for solution, but dissolve with ease in the acids.

This triple salt may be readily produced by adding ammonia to phosphat of magnesia, and the form of the artificial as well as of the native salt, is usually a short three-sided prism, terminated by a pyramid of three or six sides.

Fourcroy gives the following distinctive characters of this salt: it dissolves readily in the acids, more so even than phosphat of lime: dilute sulphuric acid in particular forms a clear solution. Ammonia only separates some small flocculi from this solution, whereas it totally precipitates phosphat of lime. The caustic alkalies separate ammonia from this calculus in sensible fumes; they do not dissolve it, but take up the phosphoric acid and leave the magnesia pure. By all these chemical properties this calculus may be readily distinguished in analysis.

Phosphat of Lime Calculus.

The surface of this calculus is generally of a pale brown,[i] and so smooth as to appear polished. When sawn through it is found very regularly laminated, and the laminæ in general adhere so slightly to each other as to separate with ease into concentric crusts. Sometimes the laminæ are striated in a direction perpendicular to the surface, giving a crystallized fibrous texture. This calculus dissolves totally and slowly in nitric or muriatic acid, and the muriatic solution crystallizes on evaporation. The phosphat of lime is precipitated by ammonia. Before the blowpipe this calculus at first becomes slightly charred, owing to the burning of some gelatin or other uniting animal matter with which it is intermixed, but it soon becomes perfectly white, and at last fuses into an opake globule. This fusibility depends on the considerable proportion of phosphoric acid which it contains, and in this it differs from the common earth of bones, which holds an excess of lime, and is therefore infusible *per se*.

Calculus, with Oxalat of Lime. Mulberry Calculus.[k]

This calculus is the hardest and heaviest of all these substances. Its colour is generally of a dark chocolate-brown externally, and irregularly grey within. Its surface is covered with tubercles or rounded knobs like the mulberry: when sawn through it gives the same smell as bone or ivory. It is soluble with difficulty in acids: the caustic alkalies have no action upon it, but when a carbonated alkali is boiled with it for a few minutes, it is completely decomposed, carbonat of lime is deposited, and the liquor contains the oxalat of the alkali used, mixed with a little phosphat. If acetited lead is added, a compound precipitate of oxalat and phosphat of lead is formed, to which if sulphuric acid is added, sulphat of lead is produced, and the oxalic acid remains in the supernatant liquid, and may be procured in its proper cry-

[i] Wollaston.

[k] Wollaston, Fourcroy.

ſtallized form. This calculus, when calcined in the open air, blackens, and gives an ammoniacal ſmell and the other products of ſoft animal matter, and a white powder finally remains, which conſiſts of quick-lime and phoſphat of lime. The quick-lime is that portion of this earth which was united to the oxalic acid, and its production or complete calcination is a perfectly diſtinguiſhing mark of this ſalt, as no other calcareous ſalt has yet been diſcovered in calculus but the phoſphat, and the acid of this latter is not deſtructible by fire.

The very extenſive and accurate reſearches of Meſſrs. Fourcroy and Vauquelin, on urinary calculi, have diſcovered to them the twelve following diſtinct ſpecies, with the enumeration of which we ſhall conclude this article, referring the reader to the original for a more complete deſcription.[l]

Sp. 1. *Calculi of Uric Acid alone.*

Theſe, which the moſt frequently occur, are diſtinguiſhable by their reſemblance to wood in colour, by having a denſe radiated texture, and by being entirely ſoluble in cauſtic alkali, without giving any ſmell. Their analyſis has been already mentioned. Sp. gr. = 1.27 to 1.78.

Sp. 2. *Urat of Ammonia.*

Theſe are pale-brown, diſpoſed in fine brittle laminæ, with a nucleus in the middle; ſoluble in cauſtic alkali, with diſengagement of ammonia. Muriatic acid takes away the ammonia and leaves the uric acid pure. Sp. gr. = 1.225 to 1.720.

Sp. 3. *Oxalat of Lime. Mulberry Calculi.*

The colour of theſe calculi is brown; the ſurface mamillated, ſometimes approaching to prickly: they are hard, denſe, and take a fine poliſh; and when ſawn give out the ſmell of raſped bone. They are inſoluble in cauſtic alkalies, ſoluble in acids, and when calcined leave pure lime. They alſo abound with an animal matter, like gelatin. Sp. gr. = 1.428 to 1.976.

Sp. 4. *Uric Acid and Earthy Phoſphats, in two diſtinct layers.*

Their colour is white like chalk, they are friable, and contain a nucleus of uric acid, and the phoſphats externally. They can only be diſtinguiſhed when ſawn through. Sp. gr. very variable.

Sp. 5. *Uric Acid and Earthy Phoſphats intermixed.*

The external characters of theſe calculi are extremely variable. Sometimes they appear homogeneous, at other times they are marbled or veined like the onyx. The colour is grey, never of a chalk white, and they are often ſoapy to the touch. Sp. gr. 1.213 to 1.739.

Sp. 6. *Urat of Ammonia and Earthy Phoſphats, in diſtinct layers.*

Theſe reſemble Sp. 4. in appearance, and can only be diſtinguiſhed by analyſis. Generally the nucleus is the urat, and the phoſphats are external; but ſometimes it is the reverſe. Sp. gr. 1.312 to 1.761.

Sp. 7. *Urat of Ammonia and Earthy Phoſphats intermixed.*

Theſe are ſcarcely diſtinguiſhable but by analyſis. Their texture appears at firſt very uniform, but attentive examination will ſhew their diſtinct laminæ of the component ſalts.

Sp. 8. *Phoſphat of Lime and Ammoniaco-Magneſian Phoſphat.*

This ſpecies is of a pure chalk-white, friable, inſoluble in alkalies, diſſolves in weak acids: ſometimes it is of an enormous ſize. Sp. gr. only from 1.138 to 1.471.

Sp. 9. *The nucleus Oxalat of Lime, and covered with a thick coating of Uric Acid.*

This variety can only be diſtinguiſhed by the eye when ſawn through, when each ſubſtance may be recogniſed by its peculiar marks. Sp. gr. = 1.341 to 1.754.

Sp. 10. *A nucleus of Oxalat of Lime, and inveſted with earthy Phoſphats.*

This too requires to be ſawn through to be diſtinguiſhed. It is not uncommon. Sp. gr. = 1.168 to 1.752.

Sp. 11. *Uric Acid or Urat of Ammonia, earthy Phoſphats, and Oxalat of Lime.*

Sp. 12. *Uric Acid, Urat of Ammonia, earthy Phoſphats, and Silex.*

This is made a diſtinct ſpecies on account of the ſilex, which however is very rare.

The above claſſification appears to us ſomewhat too complicated, and many other varieties might doubtleſs be found which would have as good a claim to be conſidered as diſtinct ſpecies as ſome of thoſe here enumerated. It will ſerve however to ſhew the very various nature of urinary calculi, and the total abſence of any one common chemical property; and hence may be demonſtrated the impoſſibility of finding a ſingle ſolvent which would apply to every caſe of this formidable diſeaſe.

URINE. Harn. *Germ.*

Human urine is an extremely compound fluid, but one with the nature of which we are now very accurately acquainted on account of the many excellent and accurate analyſes partial or compleat which it has undergone from ſeveral excellent chemiſts, among whom we may particularly mention Mr. Cruikſhank[m], and a moſt elaborate and maſterly analyſis by Meſſrs.

[l] Fourcroy's Syſtême, &c. tom. 10.

[m] See Rollo on Diabetes.

Fourcroy and Vauquelin.[b] Its composition has been partially explained under the article *Phosphorus* and *Phosphats*, as it was the substance from which phosphorus was first extracted.

The substances which unquestionably compose healthy urine before any change has been induced by putrefaction or artificial heat, are the following, viz. water, phosphoric acid, muriatic acid, uric acid, benzoic acid, carbonic acid, soda, potash, ammonia, lime, magnesia, gelatin, and a very singular substance peculiar to this fluid, to which was formerly given the vague term of a saponaceous extract, but which has more properly been called urea (urée) by the French chemists above mentioned. Besides these component parts, Proust and some other chemists have admitted a peculiar resin, to which the colour and odour is attributed; sulphur, and sulphuric acid, united partly with the soda and partly with the lime. But these three last substances are doubtful, and they may be passed over.

Of the above mentioned indubitable ingredients of urine all the acids are nearly, but not entirely, saturated with one or other of the respective bases (for a slight excess of acid is shewn in recent urine by its reddening litmus) so that a number of neutral salts are formed, and may be actually extracted by simple processes. Of these the most important are, muriat of soda and potash; phosphat of lime; phosphat of soda; and phosphat of soda with ammonia, a salt long celebrated under the term *Microcosmic salt*, or *Fusible salt of Urine*. Besides these, after putrefaction has begun in this fluid, a considerable quantity of ammonia is generated, which not only saturates the excess of acid, but gives a very sensible alcalescency, and causes the production of some other neutral salts, particularly the urat of ammonia; benzoat of ammonia; and, by uniting with the phosphat of magnesia it forms the triple ammoniaco-magnesian phosphat described in the article of urinary calculus.

Urine, recently made by a person in health, is a clear yellow fluid, varying in specific gravity from 1.033 to 1.005,[c] according as it is more or less watery, of a peculiar smell, a very acrid saline taste, and slightly acidulous so as to redden litmus. After standing for some hours it becomes turbid, and a red matter is deposited, which is chiefly uric acid, and may be re-dissolved by heating the urine.

When urine is exposed to a gentle heat in an evaporating vessel a steam arises, impregnated with an urinous odour, and a scum arises with many globules of gas entangled in it, which are chiefly carbonic acid.[d] As the evaporation advances the colour deepens to a dark red, and soon a whitish flocculent coagulum is deposited, and the steam acquires an ammoniacal smell. At this period the excess of acid existing in recent urine is lost, and on the contrary it turns syrup of violets green, which, together with the acquired ammoniacal smell, indicates the formation of a quantity of this alkali by the action of the heat. This circumstance too has another effect, which is to precipitate the phosphat of lime which was held in solution by the excess of acid, and the whitish coagulum consists of this earthy salt, together with an animal matter of the nature either of gelatin or albumen, and of some urat of ammonia. When the evaporation is continued till the liquor has a syrupy consistence, this, when decanted from the sediment, and set in a cool place deposits a considerable quantity of brown dirty crystals. To separate the whole of these, the supernatant liquor should be alternately evaporated and set by to cool, till the whole is brought nearly to dryness. By re-dissolving all the foul crystals in warm water and again crystallizing, the salts may be obtained pure; but for the purpose of analysis it is better first to digest the entire mass, both crystals and residue, with good alcohol, which will not sensibly act on the salts, but will dissolve the extractive matter with which they are mixed, and that of the residue, which consists chiefly of the *urea*.

The salts consist of the muriats of potash and soda, phosphat of soda, and of the phosphat of soda with ammonia, or *fusible salt*. If after being redissolved, the solution is strongly evaporated and set by to cool, a confused assemblage of crystals is formed, which was formerly considered without much distinction, as the native salt of urine. But if the solution is allowed to evaporate spontaneously, the muriats first separate, after which small crystals of phosphat of ammonia are formed, and along with them larger crystals of simple phosphat of soda, which latter may be distinguished by their size, by their form of compressed four-sided prisms, by efflorescing, and by running into an opake glass when melted; whereas the pure phosphat of ammonia when heated parts with its alkali, and a clear globule of phosphoric acid is left. (For the further habitudes of these two salts see the article *Phosphats*.)

The above simple method of analysis there-

[b] Ann. Chim tom. 31 & 32. [c] Cruikshank. [d] Proust.

fore will give the following products: viz. 1st. a flocculent deposit composed of uric acid, phosphat of lime and a little albumen or gelatin: 2d. an alcoholic solution containing the proper extractive matter or urea: and 3d. a watery solution of the alkaline muriats and phosphats. With regard to the relative proportions of these, Mr. Cruikshank finds that 36 oz. of healthy urine may yield about 1 oz. of solid contents, of which he estimates the muriatic salts to be about 3 drams; the alkaline phosphats to be 3 dr. 50 grs; the deposit of phosphat of lime and uric acid to be 25 grs; and the extractive matter or urea to be 3 drs. 40 grs.

Some rough estimation of the relative proportions of the muriats and the phosphats in the entire salt of urine may be made by heating them strongly, by which if the muriats are very prevalent, the mass will strongly decrepitate and fuse with difficulty; but if the phosphats more abound the whole will readily run into thin fusion. The uric acid and phosphat of lime may be easily distinguished by dissolving them in dilute nitric acid and evaporating to dryness, by which the dry mass when warm will assume a deep rose colour, if the uric acid is present, and the solution will stain the fingers; but if only phosphat of lime is present no such effect will be produced. Calcination in a red heat will destroy the uric acid, and will leave the phosphat of lime as a white friable mass.

We shall pursue the analysis of urine no further than to detail some of the effects of reagents upon urine, and the characteristic properties of urea.

Pure ammonia, and the fixed alkalies, and the alkaline earths dropped into healthy urine, produce a slight cloudiness which settles into a precipitate of phosphat of lime. This is owing to the neutralization of the acid which held it in solution as before explained.

Infusion of galls or oak-bark gives a small precipitate of tan, which amounts on an average to about 1 grain in an ounce of urine.

Muriat of barytes causes a copious dense precipitate of phosphat of barytes, which amounts to about 13 grs. from 4 oz. of healthy urine according to Mr. Cruikshank, which is equivalent to about 24 grs. of microcosmic salt.

Acetited lead produces a copious precipitate, which consists of phosphat and muriat of lead. These may be separated by digestion with about 20 parts of distilled water, which will dissolve the muriat of lead and leave the phosphat. The latter distilled with charcoal yields *phosphorus*, as mentioned under that article.

We proceed to describe the principal properties of the saponaceous extract of urine or *Urea*.

Mr. Cruikshank had found that this was that part of the urine which peculiarly yielded carbonat of ammonia when distilled, and he has mentioned the following singular habitudes with nitric acid. If to one oz. of this extract be added as much nitrous acid diluted with an equal weight of water, a violent effervescence accompanied with the disengagement of nitrous gas will take place, and when the action has ceased, and the liquor become cold, a number of shining crystalline scales resembling the acid of borax, will be deposited, which when dried on blotting paper will weigh about 6 or 7 drams, and will have the shape of flat rhomboids with a smooth greasy feel. These crystals are much more soluble in hot than in cold water; dissolve in alcohol; have decidedly acid properties; and are readily dissolved in sulphuric and muriatic acid. Their solution in water does not render lime-water turbid, nor does it act upon acetite of lead, so that it is neither oxalic nor phosphoric acid. When heated, this salt melts and evaporates in white smoke, and a reddish flame similar to nitrat of ammonia.

To these distinguishing properties of urea, the researches of Fourcroy and Vauquelin have added the following: to obtain it in the greatest purity, urine should be evaporated slowly to dryness, and the residue digested with alcohol, which will leave most of the salts untouched, but will dissolve the urea mixed with a little benzoic acid, from which it cannot well be separated, but which is in such small quantity as not much to interfere with the properties of pure urea. If this alcoholic solution is evaporated to the consistence of syrup and allowed to cool, the urea separates in imperfect quadrangular plates, of a brilliant yellowish white, which also contain a little muriat of ammonia. In this state it has an extremely fetid smell, strongly adheres to the vessel that contains it, is hard and granular, but highly deliquescent when exposed to the air.

When urea is heated *per se* in a retort with a moderate fire, a white smoke first arises, which crystallizes in the neck of the receiver, and is benzoic acid. After this comes carbonat of ammonia, which also crystallizes, and this product continues unchanged to the end of the process, without the production of any liquid, watery or oily. The vessels are filled with an intensely fetid smell, resembling that of putrid fish. The residue in the retort is blackish and dry. If farther heated, white fumes of muriated

ammonia rise, and the carbonaceous residue exhales an odour of prussic acid when moistened. Urea is extremely soluble in water, and the solution when kept without addition does not easily alter, but on adding any albuminous matter it ferments, and acetite of ammonia appears in the liquid.

When the watery solution of urea is distilled, it is resolved almost totally into liquid carbonat of ammonia, which is collected in the receiver.

The effect of nitric acid upon this singular substance has been already partly mentioned. The effervescence produced by this acid is owing to the extrication of a vast quantity of azotic gas, mixed with carbonic acid.

The caustic fixed alkalies readily dissolve urea, disengage a good deal of ammonia from it, and the solution contains the benzoic, acetous, and carbonic acids, united with the alkali employed.

Another remarkable property of urea is the disposition which it gives to muriat of soda mixed with it to crystallize in octohedrons, and muriat of ammonia in cubes; whereas the natural form of these salts is exactly the reverse. Thus the common salt obtained in evaporating urine is always at first octohedral, but on calcining it to get rid of the urea, it appears on re-solution and crystallization in its natural cubic form. The like effect is produced by mixing cubical common salt with urea and crystallizing it, when it assumes the octohedral form.

This remarkable substance requires further examination.

The urea almost entirely disappears from urine during that singular disease the *Diabetes Mellitus*, and a very large quantity of saccharine matter is produced, which latter may be extracted in abundance by evaporation and clarification, and has actually been brought to a very close resemblance of Muscovado sugar, and by digestion with nitric acid, yields a large quantity of oxalic acid.

V

VARNISHING[a], and LACQUERING, the art of.

A varnish, in the most extensive application of the term, is any fluid, which when spread thin upon a solid substance adheres to it, and, becoming dry, forms upon its surface a shining coating impervious to the air, and to moisture.

In treating of this subject the most convenient method of arranging it will be according to the nature of the menstrua from which the different varnishes derive their fluidity. These menstrua are three in number, namely alcohol, essential oil, and fat oil.

The solid substances which by solution in the above menstrua compose the body of the different varnishes are the following.

1. Benzoin.

This substance is used in compound alcoholic varnishes, chiefly on account of its fragrant odour: by itself it forms a tenacious but soft varnish, which requires the addition of some of the harder resins.

2. Lac.

This is one of the most useful ingredients in alcoholic varnishes, it forms a body of great toughness and hardness: the only objection to it is its colour, which is a brownish red.

3. Mastich.

This is a resin of prime importance to the varnisher; if well selected it has scarcely any colour, and possesses both toughness and hardness in a very considerable degree.

4. Anime.

This resin is employed in some compound alcoholic varnishes, chiefly on account of its agreeable odour.

5. Elemi.

Of this resin there are two sorts, the Ethiopian and South American. The former is greatly preferable to the latter; it is of a solid but tough consistence, a greenish colour, and possesses an odour resembling that of fennel: it communicates to the compound varnishes great toughness and durability.

6. Sandarach.

This resin communicates remarkable splendour to alcoholic varnishes, but on account of its softness requires to be mixed with the harder and tougher resins.

7. Turpentine.

Almost all the different varieties of turpentine are employed by the varnisher: they afford glossiness and body at small expence, but require the admixture of some of the harder resins.

8. Gamboge. 9. Dragon's blood.

These are never employed by themselves, but are used in small proportions for the purpose of colouring compound varnishes, especially those used in lacquering.

[a] Tingry on Varnishing—Handmaid to the Arts—Imison's Elements of Science and Arts. Vol. II.

10. Copal.

This valuble ſubſtance is employed in all the three kinds of varniſh, to which it communicates an uncommon degree of hardneſs.

11. Amber.

This is alſo a very valuable ingredient, but its application is principally confined to the coloured and opake oil varniſhes.

12. Aſphaltum.

This bitumen is extenſively uſed in the beſt black oil varniſhes.

13. Caoutchouc.

This ſubſtance is uſed only in the oil varniſh with which balloons are covered.

§. 1. *Alcoholic varniſhes.*

Alcoholic varniſhes are prepared with leſs trouble than others, they are eaſily applied, they ſoon dry, and are entirely free from any diſagreeable odour; on this account they are in very general eſtimation. They are however in return, very liable to crack, or ſcale off, and are incapable of reſiſting blows or long continued friction.

The compoſition of theſe varniſhes, though upon the whole ſufficiently ſimple, requires a few precautions which we ſhall proceed to mention. In the firſt place, care ſhould be taken not to add more reſin than the ſpirit can take up; for moſt reſins, however homogeneous they may appear to be, conſiſt of parts unequally ſoluble in alcohol; the conſequence of a ſuperfluity of reſin therefore will be, that the moſt ſoluble parts alone will be taken up, and the reſulting varniſh will be found to be much ſofter and leſs durable than if only ſuch a quantity of reſin was added as juſt ſufficed to ſaturate the alcohol. Indeed the very beſt way of proceeding is to add the reſin by ſmall portions at a time, taking care not to add a freſh quantity till the whole of the preceding is taken up.

Secondly, a mixture of two or more reſins is ſoluble in a leſs quantity of alcohol than would have been required for the ſolution of each ſeparately. This is particularly the caſe with thoſe compounds into which copal or ſandarach enter; theſe ſubſtances, eſpecially the former, being but very ſparingly ſoluble by themſelves in alcohol.

Thirdly, much depends upon the purity of the alcohol. If diluted to a certain degree with water it is incapable of acting even on the ſofteſt reſins; and for copal varniſhes the higheſt poſſible degree of rectification is abſolutely eſſential. The addition of camphor ſingularly facilitates the ſolution of copal and the more intractable reſins, but if uſed in too great a proportion it makes the varniſh mealy, and diminiſhes its tenacity.

Fourthly, during the ſolution of the reſins it is expedient that they ſhould expoſe as large a ſurface as poſſible to the action of the ſpirit; for it not unfrequently happens, eſpecially when heat is applied, that the reſins run together into a tough maſs, after which their ſolution goes on very ſlowly: this inconvenience may be obviated by mixing the reſins with rather coarſely pounded glaſs.

The following are ſome of the moſt approved receipts for alcoholic varniſhes.

1. Take of clean maſtich 6 ounces; and of ſandarach 3 ounces, and reduce the mixture to fine powder in a clean Wedgwood mortar: to this add 4 ounces of coarſely pounded glaſs, and pour the mixture into a three pint flaſk containing a quart of highly rectified alcohol: ſtop the flaſk looſely with a cork, and let the ingredients digeſt together in a warm room for three days, ſhaking the mixture frequently in the interval. Then melt three ounces of very clear Venice turpentine, by putting it into a cup ſet in hot water, and as ſoon as it is perfectly liquefied pour it into the alcoholic ſolution, alſo previouſly warmed, and then digeſt the whole in hot water for two hours; ſtirring it up frequently with a rod of glaſs, or a ſtick of white wood. When the digeſtion is finiſhed let the flaſk ſtand quiet for about a week in a warm room, and after that ſtrain the varniſh into a bottle through a little cotton wool.

2. Take of copal that has been liquefied, and afterwards very finely pounded, 3 ounces, of clean maſtich 3 ounces, of gum ſandarach 6 ounces, and of pounded glaſs 4 ounces: mix the ingredients with a quart of alcohol and digeſt them as already directed: then add 2½ ounces of clear turpentine.

This is a ſtrong and durable varniſh which may be applied to chairs and other articles of furniture.

3. Take of ſandarach 4 ounces, of ſeed lac 2 ounces, of maſtich 2 ounces, and of elemi 1 ounce; digeſt the whole in a quart of alcohol moderately warm, and when the ſolution is compleat add 2 ounces of Venice turpentine. This forms a good varniſh for violins and other muſical inſtruments.

4. Take of ſeed lac 8 ounces, and digeſt it for three or four days in a warm place with a quart of alcohol; when the ſolution is compleat ſtrain it through flannel to ſeparate the impurities, and the clarified liquor is the common lac varniſh.

5. Take of mastich half an ounce, of white frankincense a quarter of an ounce, of sandarach half an ounce, of benzoin half an ounce, and dissolve the ingredients in a pint of highly rectified alcohol: a colourless varnish is thus formed, which is employed for defending the silvering of clock-faces, of barometer scales, and other similar articles, from the action of the air.

6. Take of sandarach 6 ounces, of elemi 4 ounces, of anime 1 ounce; pound the whole together, and then add 4 ounces of coarsely pulverized glass: infuse the mixture in a quart of rectified alcohol, and add at intervals as the solution goes on half an ounce of camphor. The result is a very good colourless varnish for boxes of *papier maché* and similar articles.

7. A similar varnish to the above but somewhat coarser, is composed of white frankincense 6 ounces, anime and elemi of each two ounces, pounded glass 4 ounces, and a quart of alcohol.

§. 2. *Essential Oil Varnishes.*

The high price of most of the essential oils is such as to preclude the varnisher from the use of them; oil of lavender is occasionally employed, but the usual menstruum is oil of turpentine. The purity of this latter fluid is of the utmost importance: that which is commonly sold at the oil and colour shops, though sufficiently pure for oil painting, will very rarely answer the purpose of the varnisher, who if he wishes to save himself from much mortification and disappointment will apply for this article to Apothecaries' Hall, London, where it is constantly to be procured in the utmost purity.

Varnishes with oil of turpentine and the resins are somewhat softer but considerably tougher than those prepared with alcohol; hence they are not so liable to crack and scale off. They are principally used for varnishing oil paintings, for mixing up colours with, and for lacquering. A composition applicable to the first of these purposes is the following.

8. Take of pure and washed mastich 12 ounces, and of pounded glass 5 ounces, infuse the mixture in a quart of pure oil of turpentine, adding at intervals half an ounce of camphor in small pieces; when the mastich is dissolved add to the warmed fluid an ounce and a half of clear turpentine previously melted, and stir the mixture together till it is thoroughly incorporated.

Several of the copal varnishes may be also arranged under this section, especially those that are best fitted for varnishing articles of wood and pasteboard. Several of these have been already described under the article COPAL, to which we refer the reader. To those may be added the following very simple and very efficacious one.

9. Take from 3 to 4 ounces of copal that has previously been liquefied in as gentle a heat as possible, and 20 ounce measures of the purest oil of turpentine; put this latter in a mattrass set in boiling water, and add the pulverized copal in small quantities at a time, in proportion as it is dissolved. If the materials are good, and the process well conducted, somewhat more than 3 ounces of copal will be taken up, and the liquid will be a little cloudy: by standing for a few days it will become clear, and should then be strained through cotton. This is a thick varnish, and will generally require to be diluted with a little warm oil of turpentine before it can be used: it forms a very hard and durable glazing, which will dry in summer in the space of two or three days, or in a less time if put into a warm stove.

§. 3. *Fat Oil Varnishes.*

These are tougher and less liable to crack than the preceding, and by exposure to a proper degree of heat may be made to acquire a very great hardness: they are however very long in drying without the assistance of a stove, and give out an extremely disagreeable odour during drying: they are also for the most part high coloured, and are therefore seldom used by themselves, but mixed up with some opake body colour. The materials employed in the composition of these varnishes, with the exception of mere colouring substances, are the following, copal, amber, asphaltum, drying oil, and oil of turpentine.

The most colourless of the fat varnishes is thus prepared.

10. Take of copal liquefied, according to Tingry's method, and finely pulverized, 4 ounces, of drying linseed oil and oil of turpentine, each 10 ounces; put the whole into a mattrass, and apply a very gentle heat till the copal is dissolved: this being done, let the varnish stand for a few days to clear, and afterwards strain it through cotton. This forms a solid and nearly colourless glazing, and dries easily at the common temperature.

11. Take of picked copal 16 ounces, and melt it in a clean iron pot with as gentle a heat as possible, when its fusion is compleat, pour in 3 ounces of drying linseed oil boiling hot, and incorporate the ingredients by stirring; then remove it from the fire, and while it is yet

warm pour in a pint of oil of turpentine, also warm; strain the varnish before it gets cold through a piece of linen, and bottle it. The older it is before being used the better. This is a very valuable varnish though higher coloured than the preceding; when dried carefully in a stove it becomes very hard. Amber varnish is reckoned harder than copal varnish, on which account it is preferred for some works, it has the disadvantage however of being much deeper coloured. To prepare this varnish,

12. Take of amber coarsely pounded 16 ounces, and melt it in a clean iron pot, then add to it 2 ounces of melted lac and 10 ounces of drying oil boiling hot; incorporate the whole accurately by stirring, then remove it from the fire, and add a pint of warm oil of turpentine.

The beautiful black varnish used by the coach-makers is thus prepared.

13. Take of amber 16 ounces, and melt it in a clean iron pot, then add to it half a pint of drying linseed oil boiling hot, and 3 ounces of rosin, and the same quantity of asphaltum, each in fine po der, stir the materials together till they are thoroughly melted and incorporated together; then remove the varnish from the fire, and add to it a pint of warm oil of turpentine.

The above oil varnishes are intended to dry to a very hard consistence: those however that are employed for making silk and linen water and air tight are required to be tough, without any degree of hardness. A varnish of this kind, which was first applied to balloons, is thus composed.

14. Take of the best oil of turpentine 3 ounces, and of caoutchouc in slips a third of an ounce; put the whole in a close corked bottle, and keep it at the usual temperature for three or four days, in which time the caoutchouc will for the most part be dissolved, forming a tenacious thick fluid; pour this into a pint of drying linseed oil, and heat the mixture for a few minutes nearly to boiling, then take it from the fire and strain it while warm through a piece of linen. This is a very effectual varnish, but it is long in drying. The following therefore is to be preferred.

15. Take of very drying linseed oil half a pint, and of birdlime 1 pound, put the mixture in an iron pot, and heat it nearly to boiling, till the birdlime ceases to crackle, then pour in 2½ pints more of drying oil, and boil it for about an hour with constant stirring, taking care that it does not boil over. When it has acquired so much tenacity that a little rubbed between two knife blades will draw out into threads on the separation of the blades from each other, it may be removed from the fire, and well mixed with a quart of oil of turpentine, and then strained and bottled. In order to apply it, the silk or linen must be quite dry and the varnish lukewarm; a thin coat is to be first laid on on one side, and about twelve hours after two other coats should be laid on one on each side, and in twenty-four hours after the stuff will be dry enough to be used.

§ 4. *Of Lacquers.*

A lacquer is a transparent varnish applied to the surface of metals, both for the purpose of protecting them from the action of air and moisture, and for heightening their colour and bringing it nearer to that of gold. The metals that are commonly lacquered are brass and tin. The following are some of the best varnishes for the purpose.

17. Take of turmeric pulverized 1 ounce, and of saffron and arnotta each 2 drachms; infuse them at a moderate temperature for a week or more in a pint of rectified alcohol: separate the yellow tincture thus obtained, by straining through a piece of clean linen, and add to the clear liquor three ounces of good seed lac: let the materials digest together for some days in a bottle, with frequent shaking, and then strain off the clear part, which is the lacquer. If the piece of brass to which it is to be applied is large, as a lock for example, it is to be warmed, and the lacquer also warm is to be spread on with a brush; if the articles are small they are to be made up into packets, then warmed and afterwards dipped into the varnish.

Another lacquer for brass still cheaper than the foregoing, and nearly as good, is made by substituting half a drachm of the best dragon's blood instead of the saffron and arnotta.

The following varnish may be applied to lamps and other articles of tinned ware, in order to make them resemble brass.

18. Take of turmeric one ounce, and of dragon's blood two drachms; infuse the ingredients in a pint of alcohol, and when the tincture is compleated, strain it through a piece of clean linen, and add to the clear liquor three ounces of seed lac; in a few days the solution will be compleated, after which the varnish is to be strained and is then fit for use.

One more lacquer remains to be mentioned, namely that which is employed in the preparation of gilt leather as it is called. The appearance of gilding is produced on leather by fixing upon it, by means of strong size, very highly burnished tinfoil or silver leaf, and then coating

the polished surface over with the following varnish.

19. Take of fine white resin 4½ lbs. of common resin the same quantity, of gum sandarach 2½ lbs. and of common aloes 2 lbs.: melt the whole over a gentle fire, stirring them well at the same time with an iron spatula; when the fusion is compleat add by degrees 7 pints of linseed oil, and make the whole boil for six or seven hours, stirring it carefully all the time. When the varnish begins to get ropy, stir in half an ounce of red lead finely pulverized: as soon as this latter is compleatly dissolved remove the varnish from the fire and strain it while warm through a linen or flannel bag.

VEGETABLE MATTER.

Having already noticed at length in their proper places the different vegetable principles, and such individual vegetable substances as have received any thing like an accurate chemical analysis, there remain but a few words to be said on the general subject.

Vegetable matter, though in its ultimate analysis it is composed for the most part of oxygen, hydrogen, carbon, and azot, is made up of a number of secondary compounds, which we shall proceed to enumerate.

The most important of all, if we have regard to its quantity, in which it greatly exceeds all the rest put together, is *vegetable fibre* or *Wood*. This is to plants what bone, muscle, and cartilage are to animals; to this they are entirely indebted for their stability and the resistance which they are able to oppose to external violence: it constitutes the greater part of all woods and barks; of the green epidermis of herbaceous plants, of the network of leaves, and of the fine downy fibres in which the seeds of cotton and various other vegetables are imbedded. It consists of carbon, oxygen, hydrogen, and a little azot. By dry distillation it yields hydro-carbonous gas, carbonic acid, empyreumatic acetous, or pyroligneous acid, with a little ammonia, and a little volatile oil; a large proportion of charcoal remains behind in the retort, still exhibiting in a very perfect manner the texture of the wood. There is no animal substance at all analogous to vegetable fibre.

The next perhaps in quantity is *fecula* or starch. It is contained in all seeds, and more sparingly in most of the bulbous, tuberous, and other fleshy roots. It is not ascertained whether azot enters into its composition; it certainly however affords no ammonia by dry distillation. It appears to be absolutely peculiar to the vegetable kingdom.

Extract is another of the peculiar vegetable principles; but though nothing analogous to it exists in the animal kingdom, yet it affords ammonia both by dry distillation and by the action of quicklime; in the former case indeed the ammonia is masked by the contemporaneous production of empyreumatic acid, but it may readily be set at liberty by means of the fixed alkalies.

Another vegetable principle is *Tannin:* it is contained in certain barks, woods, and leaves, and affords by dry distillation an empyreumatic acid but no ammonia. It may be considered as peculiar to vegetables, although it appears from Mr. Hatchett's experiments that a substance very similar to tannin may be procured by the action of nitric acid on various kinds of animal matter previously charred.

Gum mucilage is another of the peculiar vegetable principles to which nothing analogous has yet been discovered in the animal kingdom: it resides chiefly in the barks of trees, and in a few of the bulbous roots. By dry distillation it affords an empyreumatic acid, from which however quicklime sets at liberty a quantity of ammonia, thus showing that azot enters into the composition of this substance.

Volatile oil is also peculiar to the vegetable kingdom: it occurs in the bark, the wood, and the covering of several seeds: it appears to consist entirely of oxygen, hydrogen, and carbon: it does not afford any ammonia by distilla ion.

Camphor, *Resin*, and *Balsam* also rank among the peculiar vegetable principles, and appear to consist of oxygen, hydrogen and carbon, without any azot. A few of the aromatic animal products indeed, such as musk, civet and ambergris appear to contain a portion of resin, which however differs from vegetable resin in affording ammonia by digestion with fixed alkali, and therefore contains azot.

Gum resin, *Gluten* and *Caoutchouc*, are three peculiar vegetable principles, into the composition of which a considerable quantity of azot enters, as they afford ammonia and oil by dry distillation, but no acid.

The acids peculiar to vegetables are the *tartaric*, *citric* and *gallic*, the *malic*, *oxalic*, *acetic* and *prussic*; of these however the four latter, though not originating in animal organization, may yet be produced by the action of different re-agents on several animal products.

The substances common to both vegetable and animal matter are the following, viz.

Sugar. This is contained largely in the stems of some of the grasses, in the nectaries of

all blossoms, in the pulp of certain fruits, and in many of the fleshy spindle-shaped roots; also in the milk of animals, and in human urine in a peculiar diseased state. It is much more abundant in the vegetable than in the animal kingdom, and by destructive distillation affords a large proportion of empyreumatic acid but no ammonia.

Fixed oil: This is contained in most seeds, and in the pulpy fruit of the olive, the cornel, and perhaps of a few other plants: in animals it resides in the liver, in cellular membrane, and in milk: it appears to consist of oxygen, hydrogen and carbon, with little or no azot, and affords an acid by destructive distillation.

Albumen, Fibrin and *Gelatin:* these substances are of extremely rare occurrence in the vegetable kingdom, but they constitute almost the whole of the soft parts of animals: they are composed for the most part of oxygen, hydrogen, carbon and azot, and afford by distillation ammonia and oil, but no acid.

Benzoic and *phosphoric* acids: of these, the former is found in the vegetable balsams, and in the urine of the horse, and of a few other quadrupeds: the latter, combined with lime, is very abundant in animals, constituting the principal portion of the bones and other hard parts; but is of comparatively rare occurrence in vegetables, in which it is found in combination with lime or potash.

All the above vegetable principles may be ultimately resolved into the following 15 substances, viz. oxygen, carbon, hydrogen, azot, sulphur, phosphoric and muriatic acids, oxyds of iron and manganese, potash and soda, lime, magnesia, silex and alumine, and of these the four first constitute by far the largest mass of vegetable matter.

As all animal matter is prepared by the process of digestion from vegetables, it is obvious that each of these great classes of substances must exhibit in its ultimate analysis the same simple substances. It is moreover evident from the preceding enumeration that not only the elements, but many of the secondary principles derived from them are common both to vegetables and animals, and therefore that strictly speaking there can be no essential characters by which the chemist can pronounce decisively concerning any unknown substance presented to his examination, that it belongs to the animal or vegetable kingdom. The old chemists indeed relied with confidence on the phenomena afforded by destructive distillation: if an ammoniacal liquor was produced accompanied by the odour of burnt feathers, the substance yielding it was presumed to be of animal origin; whereas if an acid liquor was produced accompanied by the odour of wood-smoke, the unknown substance was considered as belonging to the vegetable kingdom, and this, though by no means an infallible criterion, must still be considered as the best that can be adopted.

VENUS, crystals of } See COPPER.
VERDITER }

VERMILLION. See MERCURY.

VESUVIAN. *Volcanic Schorl, Volcanic Chrysolite, Vesuvian Hyacinth.—Idocrase.* Hauy.

Its colour is yellowish-brown, passing into olive and leek-green, clove-brown, and flesh and hyacinth red.

It occurs in mass, disseminated, or crystallized. The forms of its crystals are,

1. A strait four-sided prism truncated on the edges and sometimes on the solid angles; when the prism is short, the whole figure approaches near to the cube, and is occasionally even tabular.

2. A strait octohedral prism terminated by tetrahedral pyramids with truncated summits.

3. A hexahedral prism with single and sometimes double truncatures on the lateral edges, so as to give the crystal a cylindrical appearance.

The crystals are middle-sized or small, and are either solitary or in groups, or in druses; the lateral faces are slightly striated longitudinally, the others are smooth. Externally it has a brightly shining vitreous lustre; internally its lustre is glistening and unctuous. Its fracture is imperfectly conchoidal passing into fine granular and lamellar. It is usually more or less translucent; is hard, brittle, and easily frangible. Sp. gr. 3.36 to 3.42.

It fuses before the blow-pipe without addition into a yellowish-green glass. When strongly heated in a charcoal crucible, it forms a dense clear nearly colourless glass, with imbedded grains of iron: in a clay crucible it affords a dark olive green glass of considerable lustre.

Specimens both from Vesuvius and Siberia have been analysed by Klaproth with the following results.

Vesuvius.		Siberia.	
35.5	—	42.	Silex
33.	—	34.	Lime
22.25	—	16.25	Alumine
7.5	—	5.5	Oxyd of iron
0.25	—	a trace	Ditto of manganese
98.5	—	97.75	

It occurs in the lava of Vesuvius accompanied

by granular limeſtone, felſpar, mica, hornblende, zeolite, garnet, &c. The Siberian variety is found in Kamtſchatka, at the mouth of the river Achtaragda, imbedded in ſteatite, and accompanied by magnetic iron.

VESUVIAN (of Kirwan). See LEUCITE.

VINEGAR. *Eſſig*, Germ.

Vinegar is a liquor of an agreeable ſmell, a pleaſant and ſtrongly acid taſte, and of a hue varying from light red to brown ſtraw colour, and is prepared by fermenting any ſubſtance or compound which has already undergone the ſpirituous fermentation. Vinegar therefore may be made immediately from any wine, malt liquor, cyder, &c. or from the juice of the grape and other fruits, from infuſion of malt, or any ſaccharine liquid, through the intermedium of vinous fermentation. Both theſe methods are actually practiſed with compleat ſucceſs.

The chemical properties of the pure acid of the different kinds of vinegar (which appears to be the ſame in all) have been already deſcribed under the article ACETOUS ACID, and we ſhall therefore only mention the uſual proceſſes of manufacture.

To make vinegar out of a liquor containing ſuitable materials, it is only neceſſary, 1ſt. to allow ſome acceſs of air to the veſſel in which it is kept, and 2d. to keep it in a temperature rather higher than that of the atmoſphere in this climate, that is to ſay, about 75° to 80°. It is alſo almoſt eſſential where a liquor already fermented is employed, to add a portion of yeaſt, or any other ferment, for though any fermented liquor if kept in a moderate temperature in an open veſſel will ſpontaneouſly run ſour or become changed to vinegar, this change is too gradual to produce this acid in perfection, and the firſt acetified portion turns mouldy before the laſt has become ſour. But where the ſubſtance employed has not yet undergone fermentation, the whole proceſs of the vinous and ſubſequent acetous fermentation will go on uninterruptedly with the ſame ferment which at firſt ſet it in action, which happens, for example, in the making vinegar from malt or from ſugar and water.

As even vinegar is not the ultimate change which a vinous liquor ſpontaneouſly aſſumes, there is a period in the proceſs of the manufacture in which the acid is in its higheſt degree of ſtrength and perfection, after which if the proceſs is not ſtopped, the liquor ſpeedily deteriorates, the acetous acid gradually diſappears, and only an offenſive mouldy watery liquid remains, with ſcarcely any ſourneſs. It belongs therefore to the ſkill and experience of the manufacturer to know when his vinegar is compleat and fit to be drawn off and cloſely barrelled.

Vinegar was doubtleſs (as its name imports) originally made from wine, and this is the material which furniſhes it probably in the greateſt perfection, and is employed ſolely in the wine countries. It is prepared by adding wine lees to wine, which excites a new fermentation that is kept up till the whole is changed to vinegar. Any wine will anſwer the purpoſe; the beſt and fulleſt-bodied wine gives the ſtrongeſt vinegar, and that which is already ſoured and injured by keeping may be applied to this uſe. The actual method purſued in Paris is the following.[a] A quantity of wine lees is put into a large tun, and worked up with wine ſufficient to render it very fluid. This is then put into cloth ſacks, which are arranged in a large iron-bound wooden vat, the heavy cover of which is laid over them and ſerves as a preſs, that is gradually ſcrewed down till all the liquor is preſſed out. The wine, thus loaded with the extractive and tartareous matter of the lees, is diſtributed in large caſks ſet upright, through the heading of which a hole is cut which is conſtantly left open. In ſummer theſe caſks are ſimply ſet in the ſun, but in winter they are arranged in a ſtoved room. The fermentation comes on in a day or two, and when it has got to its height ſo much heat is excited that ſometimes the hand can hardly be borne in it. In this caſe it muſt be checked by a cooler air, and by adding ſome freſh wine to the caſks, and indeed it is in a due regulation of the heat that moſt of the practical ſkill of the maker conſiſts. The proceſs goes on in this way till the whole of the wine is thoroughly acidified, which requires about a fortnight in ſummer and a month in winter; after which the new vinegar is put into barrels, at the bottom of which are laid a good many chips of beech wood. Here it remains for about a fortnight, during which time it clarifies and the clear part is then drawn off and kept in well cloſed caſks. Theſe beech chips may be uſed over and over again for ſeveral years.

The natural colour of good wine vinegar is a very pale red, but a higher colour is given, if deſired, by the addition of elder-berries.

There are ſeveral ſlight variations in the mode of making wine vinegar, but which need

[a] Encycl. Arts & Met. Article Vinaigre.

not be detailed. They all confiſt in exciting a freſh fermentation in wine and keeping it up in a moderate degree till acetification is compleat. Many refuſe parts of the vine are of uſe for this purpoſe, ſuch as the huſks, the ſour ſucculent twigs, the marc or cake left in the wine preſs, and the like; and after they have once ſerved, they are ſtill more valuable, as the acid which they naturally contain, or which is evolved by them, is more readily produced.

Wine may alſo be converted to good vinegar without theſe additions, ſimply by adding wine, eſpecially when on the fret, to vinegar already made, and expoſing it to a proper heat. In this way many manufacturers proceed, keeping their caſks always full by taking out of them at intervals about a third or fourth part, repleniſhing them with wine, and again bringing the contents to the ſtate of vinegar.

In this country vinegar is chiefly made from malt. The following is the uſual proceſs in London. A maſh of malt and hot water is made, which after infuſion for an hour and a half is conveyed into a cooler a few inches deep, and thence, when ſufficiently cooled, into large and deep fermenting tuns, where it is mixed with yeaſt and kept in fermentation for four or five days. The liquor (which is now a ſtrong ale without hops) is then diſtributed into ſmaller barrels ſet cloſe together in a ſtoved chamber and a moderate heat is kept up for about ſix weeks, during which the fermentation goes on equally and uniformly till the whole is ſoured. This is then emptied into common barrels, which are ſet in rows (often of many hundreds) in a field in the open air, the bung-hole being juſt covered with a tile to keep off the wet but to allow a free admiſſion of air. Here the liquor remains for four or five months, according to the heat of the weather, a gentle fermentation being kept up, till it becomes perfect vinegar. This is finiſhed in the following way. Large tuns are employed, with a falſe bottom, on which is put a quantity of the refuſe of raiſins or other fruit left by the makers of raiſin and other home-made wines, called technically *rape*. Theſe rape tuns are worked by pairs; one of them is quite filled with the vinegar from the barrels, and the other only three-quarters full, ſo that the fermentation is excited more eaſily in the latter than the former, and every day a portion of the vinegar is laded from one to the other till the whole is completely finiſhed and fit for ſale.

Vinegar, as well as fruit-wines, is often made in ſmall quantity for domeſtic uſes, and the proceſs is by no means difficult. The materials may be either brown ſugar and water alone, or ſugar with raiſins, currants, and eſpecially ripe gooſeberries. Theſe ſhould be mixed in the proportions which would give a ſtrong wine, put into a ſmall barrel, which it ſhould fill about three-fourths, and the bung-hole very looſely ſtopped. Some yeaſt, or, what is better, a toaſt ſopped in yeaſt ſhould be put in, and the barrel ſet in the ſun in ſummer, or a little way from a fire in winter, and the fermentation will ſoon begin. This ſhould be kept up conſtant but very moderate, till the taſte and ſmell indicate that the vinegar is compleat. It ſhould be poured off clear and bottled carefully, and it will keep much better if it is boiled for a minute, cooled and ſtrained before bottling.

Vinegar contains a conſiderable quantity of colouring extractive matter, from which it can only be freed by diſtillation, the proceſs of which, together with the chemical properties of this acid, have been mentioned under the article *Acetous Acid*.

When vinegar is long kept, eſpecially expoſed to the air, it becomes muddy, acquires a mouldy unpleaſant ſmell, loſes its clear red colour and all its properties, and finally is changed to a ſlimy mucilage and water.

VITAL AIR. See Oxygen.

VITRIFICATION. See Glass.

VITRIOL, native. *Naturlicher Vitriol.* Wern.

Its colour is greyiſh or yellowiſh-white, apple or verdigris-green, or ſky-blue; when decompoſing it is covered with an ochery cruſt. It occurs in maſs, diſſeminated, ſtalactitical and capillary. Externally it is rough and dull, internally it is more or leſs ſhining, with a vitreous or ſilky luſtre. Its fracture is generally fine and ſtrait fibrous, ſometimes alſo lamellar or conchoidal. It is ſoft, brittle, tranſlucent, and has an acerb metallic flavour. It is more or leſs ſoluble in water, and is a mixture in various proportions of the ſulphats of iron, copper, and zinc.

It not unfrequently occurs in caverns and ſhafts, in argillaceous ſchiſtus, and in old mines, eſpecially ſuch as abound in blende and pyrites.

VITRIOL blue. See Copper, Sulphat of.

VITRIOL green. See Iron, Sulphat of.

VITRIOL white. See Zinc, Sulphat of.

VITRIOLATED TARTAR. See Sulphat of Potaſh.

VITRIOLIC ACID. See Sulphuric Acid.

VOLATILE ALKALI. See Ammonia.

W

WAKKE.

Its colour is generally a deep greeniſh-grey, paſſing to greeniſh and greyiſh black; it is alſo not unfrequently ſpotted reddiſh or browniſh. It occurs in maſs and cellular; the cells being either empty or filled with other minerals. Internally it is dull. Its fracture is even, paſſing into uneven and earthy. Its fragments are indeterminate and blunt-edged It is opake, acquires a little luſtre by friction, is ſoft and eaſily frangible; it is ſomewhat unctuous to the touch. Sp. gr. 2.53 = 2.89. It is readily fuſible by itſelf before the blow-pipe into a black glaſs.

It belongs to the more recent of the rocks of trap-formation, and not unfrequently incloſes petrified wood and other organic remains. It occurs in beds, and veins, and forms the baſe of many of the amygdaloids.

The cavities in the cellular variety generally contain green earth, calcareous ſpar, &c. It is often mixed with cryſtals of baſaltic hornblende, with black mica, magnetical iron ore, and native biſmuth.

For further particulars ſee TRAP.

WALKERERDE. See FULLER'S EARTH.

WATER. *Eau*, Fr. *Waſſer*, Germ.

Water at the common temperature is a perfectly tranſparent inelaſtic fluid, of a very pale bluiſh-green colour when in large maſſes, and entirely deſtitute of flavour and odour. In ordinary circumſtances it retains its liquid form only between the two extremes of 32° and 212° of Fahrenheit's thermometer, but when ſubjected to great preſſure, as in Papin's digeſter, it is able to ſuſtain nearly a red heat without being converted into ſteam: and on the other hand when the preſſure of the atmoſphere is removed, by incloſing it in an exhauſted receiver, it is convertible into elaſtic vapour by a temperature hardly exceeding 70°. Its point of congelation alſo may be protracted, by cautiouſly cooling it down without agitation, to about 22°; but at this temperature a ſlight friction is ſufficient to determine the inſtant ſolidification of the maſs, which is attended by a very ſenſible evolution of heat, as we have ſhewn at large in the article CALORIC. Water, like other inelaſtic fluids is nearly though not abſolutely incompreſſible. The ſpecific gravity of water at 60° is = 1.0, this liquid being univerſally adopted as that to which the ſpecific gravities of all other bodies are to be compared, and by which they are to be adjuſted. Other liquids increaſe in denſity by an uniform progreſſion according to the cold to which they are expoſed, but in water the period of greateſt denſity is at the temperature of 42° F. and from this point equal degrees, whether of cold or heat, produce equal changes of ſpecific gravity, ſo that water at 32° and at 52° poſſeſſes the ſame degree of denſity. The abſolute weight of a cubic foot of water at 40°, appears from ſome very accurate experiments by Lefevre Gineau to be = 437102 grs. troy, or .999.09 ounces avoirdupois; and the weight of a like bulk of water at 55° is ſtated by Prof. Robiſon at 998.74 ounces avoirdupois. The weight of a cubic inch of water at the ſame temperature is = 253.03 grs. but according to the experiments of Sir G. S. Evelyn, as corrected by Mr. Fletcher, it is = 252.506. See the APPENDIX of *Weights and Meaſures*.

At 32° Fahr. as we have already mentioned, water becomes ſolid, and in doing ſo, aſſumes a true cryſtalline texture: if a flaſk of water be ſet in a moderate freezing mixture till a conſiderable part is frozen, and the fluid portion be then poured off, there will be perceived acicular cryſtals ſhooting from the maſs, and croſſing each other at angles of 60 and 120 degrees; ſometimes alſo, though rarely, there may be perceived tetrahedral priſms terminated by dihedral ſummits. Ice when at a low temperature is conſiderably hard, tough, and elaſtic: at the celebrated palace of ice conſtructed one winter at Peterſburgh by order of the late Empreſs Catharine, there were cannon made of this material, which ſuſtained ſeveral diſcharges without burſting. The ſpecific gravity of ice is conſiderably leſs than that of water, in conſequence of which it floats upon its ſurface; a part of this buoyancy, however, is to be attributed to the bubbles of air entangled in its ſubſtance, which are diſengaged by common water in the act of congelation. The expanſive force of water while converting into ice is ſo prodigious that its limits have not yet been aſcertained: the moſt intereſting experiments on this ſubject are thoſe performed by Major Williams at Quebec:* bomb-ſhells about 13 inches in diameter, and with a thickneſs of metal exceeding 2 inches, were filled with water; the fuſe holes were then plugged up with iron bolts, and the ſhells thus charged were expoſed to the open air at a temperature between — 4° and — 19°: at

* Edin. Phil. Tranſ. Vol. II.

the moment of congelation the plugs were thrown out with a hissing noise to a distance of 300 or 400 feet, while a column of ice rose at the same time through the fuse hole to the heighth of several inches: when the plug was secured by strong springs so as to render it almost impossible to force it out, the shell itself burst with a sudden crack, and two thin plates of ice forced their way at the same time through the aperture. The greatest difference observed in these experiments between the bulk of water before and after congelation, was : 174 : 184.

Water, under the ordinary atmospheric pressure, is converted into steam, at 212° of temperature, and by so doing it expands to about 1800 times its former bulk: the elastic force which it thus acquires is very considerable, and constitutes the moving power of that most important machine, the steam engine. Steam readily and entirely condenses into water as it cools, and it is in this way, that is by distillation, that pure water is obtained; for the most delicate chemical uses, the distillation must be carried on in glass vessels, and even with every possible precaution it is by no means easy to obtain this fluid of absolute purity.

It does not appear that mere heat is capable of effecting any change in water, for steam may be passed through a red hot glass tube, and be condensed at the other end again into pure water.

A considerable affinity subsists between water and atmospheric air; for if this fluid recently distilled be exposed for a few days to the air, and afterwards be boiled or subjected to the action of the air-pump, a considerable quantity of bubbles of gas will be disengaged; there still however remains a portion combined with the water which it is very difficult to get rid of even by long boiling.

Oxygen gas is absorbed by water in preference to atmospheric air, and by means of strong agitation and pressure, according to the experiments of M Paul, of Geneva, 100 cubic inches of this fluid may be made to take up 50 cubic inches of oxygen gas, 33 cubic inches of hydrogen and 66 cubic inches of carburetted hydrogen. Water thus highly charged effervesces when the extraordinary pressure is taken off, and in this state has been used as a medicine. Any other of the permanent gasses may in like manner be combined with water, as we have mentioned when treating of these substances. For the proportions of different gasses which water at the common pressure is capable of taking up, see the article GAS.

Water is capable of combining with and dissolving the acids, the alkalies and alkaline earths, and all the compound salts; with several of these substances it unites in two proportions, forming in one case a solid, and in the other case a fluid compound; thus if calcined gypsum, or barytes, or lime, or sulphat of soda, are mixed with a certain proportion of water, the resulting mass is quite as solid as before, and during this first combination a quantity of heat is constantly extricated, but if to the salts thus saturated more water is added, solution takes place, and cold is generated. From this solution the salt may again be in most cases procured, by evaporation and cooling, in a crystalline form, in which, though solid, it is still saturated with water: this proportion of water appears to be necessary to the crystalline form of the salt, and hence is usually called its *water of crystallization*; by a dry heat it is driven off and the salt alone remains in a pulverulent or amorphous state.

A considerable affinity subsists between water and alcohol: if determinate bulks of these two fluids be mixed together, the resulting mass will be found to have a specific gravity superior to that of the mean of the ingredients, and a sensible degree of heat will be disengaged during mixture: there appears however to be no point of mutual saturation, as they will combine together in all proportions. Resins and most other substances insoluble in water, but soluble in alcohol, are precipitated from their solution by the addition of this latter fluid; as on the other hand all salts that are soluble in water but not in alcohol are precipitated by means of this from their watery solution.

Ether and water are capable of uniting in two different proportions. If equal bulks of the two fluids are shaken together, and then allowed to rest for a few seconds, the mass will divide into two distinct liquids, of which the upper and lighter is ether holding a little water, and the lower and denser is water combined with a little ether. That ether saturated with water is chemically different from pure ether, appears from its being able to dissolve caoutchouc, which this fluid when pure is incapable of doing.

None of the simple combustibles appear to be soluble in water, nor have they any marked action on this fluid at the common temperature. Even at a much higher heat hydrogen and steam exert no mutual action on each other. The effect of hot melted sulphur on water is dubious, and that of phosphorus has

not been examined: it is said that a mixture of phosphorus and sulphur at a boiling heat decomposes water, phosphuretted and sulphuretted hydrogen gas being disengaged. But of all the combustibles charcoal has the most marked action on water: if a glass or earthenware tube be filled with pieces of charcoal, and then heated red hot, and if steam be passed into it in this situation, both the water and charcoal will by degrees disappear, and there will be generated a prodigious quantity of mixed gas, consisting of carbonic acid, oxyd of carbon, and carburetted hydrogen.

Of the metallic substances, iron, zinc, tin, and manganese decompose water by the assistance of heat, hydrogen gas being produced, and the metals being reduced to the state of oxyd. Gold, silver, platina, and copper have no action on water even at a red heat; the effect of the other metals has not been examined.

The composition of water is one of the main pillars on which the theory of Lavoisier rests, it will therefore be proper to enter somewhat at large into the subject.

Water was considered by the ancient philosophers, as a simple elementary substance, undecomposable, but which by mixture with other bodies constituted the principal part of the nutriment of animals and vegetables. The first modification of this theory was by Van Helmont, who having raised plants successfully in pure water, concluded that this fluid alone is convertible into all the vegetable principles. Soon after, Boyle having procured earthy scales by long digestion of water in glass vessels hermetically sealed, concluded that this fluid was in part at least convertible into earth: Margraaf obtained the same result from the repeated slow distillation of water in glass vessels. But though there was no inaccuracy in the fact, it was demonstrated by Lavoisier that the vessels themselves during the process lost a portion of their weight exactly equal to that of the earth produced, and therefore that the earth was in all probability derived not from the water, but from the glass; a conclusion which was further confirmed by Dr. Priestley, who satisfactorily showed that water by long contact with glass at a high temperature, always decomposes a part of it, probably in consequence of its affinity for the alkali.

While these discussions were going on, the discovery of the gasseous substances commenced and soon led to an entirely new theory concerning the composition of water. The first fact of any importance was observed by Macquer who found that a bottle filled with hydrogen gas and exposed to the air burnt with a lambent blue flame unaccompanied by any smoke, and that the inside of the vessel after the combustion was lined with drops of a fluid which appeared to be water. Some time afterwards Dr. Priestley exploded in a glass vessel a mixture of oxygen and hydrogen gas, and found that the vessel became moist in the inside, and was lined with a black matter, supposed by Dr. P. to originate from the mercury by which the gasses were confined.

Induced by the above results, Mr. Cavendish[b], in 1781, mixed together 500000 grain measures of hydrogen gas from zinc and sulphuric acid, and about 2½ times as much of atmospheric air: by combustion the bulk of the mixture was diminished to about ⅘ of that of the latter gas, there were obtained 135 grs. of pure water. In order to repeat the experiment in a more unexceptionable manner he exploded a mixture of 19000 grain measures of oxygen gas and 37000 of hydrogen gas: 2950 grain measures remained unconsumed, and there were obtained 30 grs. of an acidulous fluid, which appeared to be a mixture of water with a little nitric acid. In another experiment the proportion of hydrogen was increased, and the resulting fluid appeared to be pure water, being wholly free from any acid. From these he drew the conclusion that the appearance of nitric acid was owing to accidental impurities, and that water was composed of oxygen and hydrogen. Soon after Lavoisier and La Place performed a similar experiment, from which they obtained 295 grs. of pure water, and accordingly concluded that water was composed of oxygen and hydrogen. Another well-conducted experiment with the same view was executed by Le Fevre de Gineau, of which the following are the principal particulars. 35085.1 cubic inches of oxygen gas obtained from black oxyd of manganese, and weighing 254 gros. 10.5 grains, were exploded with 74967.4 cubic inches of hydrogen gas procured from soft iron and diluted sulphuric acid, and weighing 66 gros. 4.3 grains; hence the whole weight of the gasses operated on was = 320 gros. 14.8 grains. After the combustion there remained 39 gros. 23 grains of elastic fluid consisting of a mixture of oxygen, azot, and carbonic acid, hence the amount of gas which had disappeared amounted to 280 gros. 63.8 grains. But there was produced 280 gros. 30 grains of

[b] Phil. Transf. lxxiv. p. 128.

an acidulous liquor, consisting of water with a little nitric acid, the loss of weight in the whole experiment being only 33.9 grains.

The most satisfactory experiment, however, on this important subject, was made in 1790, by Vauquelin, Fourcroy, and Seguin. The oxygen employed by them was procured from oxymuriat of potash, and the hydrogen from zinc and diluted sulphuric acid: of the former the amount was = 13475.198 cubic inches, and of the latter = 25980.563 cubic inches: the combustion was carried on very slowly, and therefore lasted several hours, at the expiration of which time there remained 987 cubic inches of gas, consisting of the following ingredients, viz.

467	Azot
465	Oxygen
39	Carbonic Acid
16	Hydrogen
987	

The proportions of the gasses that had disappeared were estimated at

Hydrogen	= 25963.563 cub. inch	= 1039.358 grs.
Oxygen	= 12570.942 cub. inch	= 6209.869 grs.
		7249.227

and the quantity of water produced was = 7245 grs. which is as near an approximation to that of the gasses consumed as can possibly be expected in experiments of this kind. The water was subjected to all the usual chemical tests, and appeared to be quite pure; there remains therefore no possible objection to the obvious conclusion from this experiment except the appearance of the carbonic acid and azot in the residual gas. Of these the former may be accounted for by supposing that a little of the carbon which zinc always contains, was taken up by the hydrogen and underwent combustion together with it: the azot was probably an accidental impurity introduced with the oxygen.

The proportion of the ingredients that compose water, as deduced from the preceding experiments, are according to

Lavoisier	15.	of Hydrogen to 85.	of Oxygen
Le Fevre Gineau .	15.2	84.8	
Vauquelin & Fourcroy	14.33	85.66	

The only objection that has been urged against the above proof of the composition of water is the following by Dr. Priestley. This philosopher having concluded, upon as we think insufficient grounds, that the greatest part of the ponderable portion of all gasses is water, maintained that in the combustion of oxygen and hydrogen gas the water that appeared was merely precipitated, and that the real oxygen and hydrogen combined together, forming the residual azot or nitric acid according to circumstances. To this however it may be replied, that the oxygen from manganese, and from most of the other sources from which it is procured, may readily be proved by the common eudiometrical processes to be mixed with a small contamination of azot; that Mr. Cavendish and others have very satisfactorily proved that the proportion of nitric acid or azot obtained depends wholly on the previous impurity of the gasses employed; and thirdly, that according to Dr. P's. hypothesis, real oxygen and hydrogen must be both of them entirely imponderable substances, for in those cases where no nitric acid appears after the combustion of the two gasses, but only a small portion of azot, he must suppose not only that this small residue of azot contains the whole of the real oxygen and hydrogen, but that as this azot still retains its gasseous form it must still consist almost entirely of water.

The effects of electricity on water serve as a further proof of the modern doctrine relative to its composition: by passing shocks along an interrupted golden or platina wire immersed in water, bubbles of gas are observed to be disengaged at every explosion, and when a quantity of air has been thus collected, if an electrical shock is passed into it, an explosion immediately succeeds, water is formed, and the gas disappears, with the exception of a minute portion which is probably atmospheric air previously held in solution by the water.

The action of certain of the metallic bodies, when heated, on steam passed over their surface, was first adduced by Lavoisier as a proof of the decomposition of water, and his deductions have been acquiesced in by most succeeding chemists. A quantity of soft iron wire being put into a glass tube and heated red hot, 100 grs. of water in the form of steam were slowly passed into the tube; the water disappeared, 416 cubic inches of hydogen gas weighing 15 grs. were produced, and the iron

wire was converted into a black brittle oxyd weighing 85 grs. more than at first. In this process, says Lavoisier, the water is decomposed, its oxygen being absorbed by the iron, and its hydrogen, the other component part, being liberated in the form of gas. Dr. Priestley, however, though he admits the fact, explains it in the following manner. The water, according to him, in part unites with the phlogiston of the metal forming hydrogen gas, while the rest of the water combines with the calx of the iron. That this black calx really contains water he endeavours to show by the following comparative experiment.* A quantity of scales of iron and of red oxyd of mercury were moderately heated, in order to render them as dry as possible, they were then each put into glass receivers of the same size and form, inverted in dry mercury, and afterwards filled with hydrogen gas from the same vessel. The focus of a burning lens was then thrown upon the metallic oxyds, and it was found that by the time 4 ounce measures of the inflammable gas were absorbed by the iron, the water was running down the side of the receiver in drops, whereas although the mercurial oxyd was heated till 8 ounce measures of gas were absorbed, there was hardly any sensible quantity of water produced. If this experiment is accurately reported (and there seems no reasonable ground for suspicion) it follows not that the phlogistic theory is true, but that the theory of the decomposition of water can derive no confirmation from it. It is indeed not improbable that there is a real difference between finery cinder or scales of iron, and the black ethiops of the same metal, the latter being a simple oxyd, and the former a hydrat, that is to say, a combination of oxyd with water.

Upon the whole it appears that the only perfectly unequivocal evidence for the composition of water is derived from those experiments in which it is actually produced by the combustion of determinate proportions of oxygen and hydrogen, and from those in which it is first decomposed and afterwards recomposed by the agency of the electric fluid. These experiments however have been performed with such particular care by the most accurate and intelligent chemists of the age, that no fact in the whole circle of chemical science is more satisfactorily demonstrated.

WATERS. Mineral.

Every natural water which flows on the earth, or is found beneath its surface, holds some foreign matter in solution, which, if it does not sensibly impart some peculiarity in taste, smell, and physical properties, may at least be detected by chemical means; and when the quantity or nature of this foreign ingredient is such as to give obvious sensible or medicinal properties, it is usually called a mineral water. The salt waters of the ocean and of some large inland lakes, are however excluded from this definition, though in every other point of view they are full as interesting as the smaller and comparatively rare springs, which have the appellation of *mineral*.

The high importance attached to mineral waters has first arisen from the extensive celebrity which they have acquired in the cure of diseases; a celebrity which many of them maintain to the present moment: and they are equally interesting to the chemist on account of the variety of substances contained in them, and the mode of their chemical union, and as often illustrating the difficult science of geology.

The analysis of mineral waters has (as might be expected) been benefited by all the improvements which have been progressively made in general chemistry, and the subject has been in particular elucidated by the labours of many excellent chemists especially directed to this object. It is still however in many cases complicated and difficult, and requires considerable skill and minuteness in manipulation, as the substances operated on are always in small quantity and often numerous.

The substances hitherto found in natural waters are the following:

1. *Oxygen Gas*, in small quantity, was first detected by Scheele. It is contained in almost every spring water, but never exceeds about $\frac{1}{100}$ of its bulk, and generally is less. It exists in very loose combination, and gives no sensible properties to the water. It is incompatible with sulphuretted hydrogen and with sulphat of iron, and therefore cannot be present when these are.

2. *Azotic Gas*, in small quantity and in loose combination exists in some waters, such as that of Buxton, and at the same time a large quantity of it usually rises in its gaseous form along with the water, and passes through it in large bubbles. This also gives no obvious sensible properties.

3. *Common Air* is contained in small quantity in all natural waters, from which the last por-

* Doctrine of Phlogiston, &c. p. 37.

tions are with great difficulty separated. This also produces no sensible change in water.

4. *Carbonic Acid.* Almost all natural waters contain a portion of this gaseous acid, but which varies extremely from $\frac{1}{100}$ or less of the bulk of the water, to an equal bulk. When the quantity is about $\frac{1}{10}$, and uncombined with any other base, it gives an agreeable pungency to the taste, and a sparkling appearance.

Carbonic acid is found, either totally unaccompanied with any other substance with which it has any affinity, or totally united with an alkaline, earthy, or metallic basis; or more commonly partly combined, and partly in excess (that is to say, more than sufficient to saturate the base) and by its excess rendering the base soluble, or, if this excess is still greater, imparting to the water the same pungency as if it were entirely unaccompanied by any other body. The only carbonats hitherto found in mineral waters are the carbonats of soda, magnesia, lime, and iron. Of these the two former are soluble in water, without any such excess of acid as to render the water acidulous, but not the two latter.

5. *Sulphuretted Hydrogen.* A considerable number of waters contain a very notable quantity of this gas, which gives its peculiar fetid smell, and nauseous, somewhat sweetish taste. In general the sulphuretted hydrogen is uncombined with any base, but there are some waters, particularly some of the hot springs, which, along with this substance, contain soda, with which it doubtless combines, and this compound often contains an excess of sulphur, which it deposits in a small quantity. Sulphuretted hydrogen is incompatible with no other gas but oxygen.

6. *Sulphureous Acid* is found in some springs, though rarely, and hitherto has been only met with in the neighbourhood of volcanoes.

7. *Sulphuric Acid* is a very common ingredient in waters, but never uncombined, and it gives a sensible acidulousness, only when the salt of which it forms a constituent part naturally exists with excess of acid, such as alum and sulphat of iron. The other combinations of this acid, and in which it is fully neutralized, are sulphats of soda, lime, and magnesia. It has only been found united with potash when they both form constituents of alum.

8. *Muriatic Acid* has only been found combined and in compleat saturation. The muriats of soda, magnesia, and lime, are very frequent, the muriats of alumine, iron, manganese, and potash, are rarely found, and the latter is even doubtful.

9. *Boracic Acid* has been found uncombined in a lake in Tuscany.

10. *Nitric Acid*, united with potash and probably with other bases, is found in those springs that come in contact with the native nitre with which Hungary and some other countries abound.

11. *Soda* is the alkali of by far the most frequent occurrence in mineral waters. It is sometimes uncombined or only united to carbonic acid, so as to give a sensible alkalescency to the taste, and to chemical tests, and causes the water to lather by agitation. These alkaline waters are generally hot.

Soda is also found united with sulphuretted hydrogen, with sulphuric acid, as Glauber's salt, and with muriatic acid, as common salt. Both these salts are very frequent in waters, and the latter often in very large quantity.

12. *Potash* has been extracted, as it is said, from one mineral water, and as late researches have shewn it to be contained in some minerals, it may probably be found in other waters.

13. *Ammonia* has been detected by Mr. Cavendish in a spring near London.

14. *Lime* is never found uncombined in water, but is contained in small quantity in almost every natural water, united with sulphuric acid as selenite, and is scarcely less frequent dissolved in water by means of carbonic acid. Muriat of lime is also not uncommon.

15. *Magnesia* is found in the same combinations as lime, but not quite so frequently.

16. *Alumine* is not unfrequent in mineral waters. Often it is merely suspended in extremely fine division, but it has also been detected in union with the sulphuric and muriatic acids.

17. *Silex.* This earth was first detected by Dr. Black in the water of the celebrated boiling springs of Iceland. As these waters contain an excess of soda, and as silex is rendered soluble in water by means of alkali, it was rationally conjectured that this, together with the great heat to which the water is exposed, caused the solution. The same earth has however been since detected by Dr. Gibbs, in Bath water, which is not alkaline.

18. *Iron* is a frequent ingredient in mineral springs, in small quantity, but sufficient to give a very sensible chalybeate taste and smell. It is generally held in solution by the carbonic acid, and is then always accompanied by carbonat of lime, and often of magnesia; but sometimes it is in the form of sulphat.

All the chalybeate waters deposit oxyd of

iron by exposure to air, so that the track of these springs on the soil is marked by a line of reddish yellow ochre.

19. *Copper* is only found as a sulphat, and in the neighbourhood of copper pyrites, from the decomposition of which it originates. It is strongly marked by the cupreous taste.

20. *Manganese* dissolved in the muriatic acid has been found.

21. Besides these ingredients there is often found dissolved in water a small quantity of a black matter, not crystallizable, soluble in alcohol, destructible by fire, which gives a black tinge to sulphuric acid, and is obviously carbonaceous. Its quantity is always too small for minute examination, but it is usually considered as a kind of *bitumen*. This appears different from the soluble part of decayed vegetable matter which water sometimes meets with and holds in solution; and is equally distinct from the mucilage which is generated in water when nearly stagnant, from the growth of confervæ and other aquatic vegetables.

Some arrangement of mineral waters has been attempted by different writers on the subject. This however is of little importance except as relates to their medicinal powers, for even among those kinds that resemble each other the most, such as the carbonated, the chalybeate, the sulphurous, &c. the individual waters often differ so much in chemical analysis as to require to be admitted as separate genera in any methodical arrangement. The distinction of warm and cold should however be noticed, the former being uniformly above the average temperature of the air into which they rise. Of these there are many in the neighbourhood of actual volcanoes, or in countries obviously volcanic, which have the temperature of 212° when they burst into day, and in all probability are much hotter before. Such boiling springs are found in Iceland, in Italy, in South America, and in great abundance in Kamschatka. In this country the Bath water is the hottest natural spring that we possess, which rises to 116°. The coolest of our thermal waters is the Matlock, which is steadily at 66° in the coldest winters.

We proceed to the best mode of examining a mineral water, in which some differences exist among the best chemists.

The physical properties of the water should be first noticed.

These are the degree of clearness or limpidity—sparkling or bubbling when poured into a glass—the taste—smell—specific gravity—and temperature. It is useful also to mark the strata of soil from which it springs, the copiousness of the spring, and whether this is affected by a dry or wet season, whether any vegetables, fishes, or animalculæ are found in it, and whether it incrusts the substances over which it flows, or deposits any sediment.

The next step is the application of *tests* of different kinds, which is of the utmost importance, as by these the nature and number of all the foreign ingredients (with one or two exceptions) may be discovered, and even some opinion may be formed of their relative quantity, and these facts are the guide by which the future analysis is conducted. Several precautions however are required in the application of tests to avoid deceitful appearances, and the tests themselves should be prepared with great care, which may be the more readily done as very minute quantities judiciously applied will answer every purpose. Most of the tests indicate the substances for the detection of which they are used, by producing a sensible turbidness which gradually collects into a precipitate. There is however with all a limit to this power of precipitation, for when two naturally incompatible salts are mixed together in very dilute solution, the decomposition is totally prevented by the great bulk of water compared to the saline matters. Thus very small quantities of sulphat of lime and carbonat of soda will coexist in the same water, and these will not be mutually decomposed till the bulk of liquid is reduced by evaporation. In like manner minute quantities of sulphat of magnesia and muriated lime, or of muriated lime and sulphat of soda, may be contained in the same water.

Another limit to the power of tests is where the intended decomposition does indeed take place, but where the quantity of liquid is so large that the resulting compound, instead of being precipitated, remains suspended in the water.

The principal tests are the following:

Litmus. The infusion or tincture of litmus sold in the shops is a thick liquor of a very dark purple, containing a great body of colour. The purple of litmus is changed to red by every acid, so that this is the test usually applied to discover any excess of acid in mineral waters. It may be used either by dipping into the water a paper stained with litmus, or by adding a drop of the tincture to the water to be examined, and comparing its hue with that of an equal quantity of the tincture in distilled water. In this latter way the change is produced more

speedily, and the power of the test is so great, that the act of blowing through litmus water, diluted so as to be barely coloured, will very sensibly alter the hue by means of the carbonic acid of the breath which unites with it. It should be remembered that paper or muslin stained with litmus spontaneously reddens by exposure to air, also that the colour is nearly destroyed by long exposure to light, so that when used as a test they should be recently stained. Litmus is also reddened by sulphuretted hydrogen.

As the acid of mineral waters is generally the carbonic, and as this acid, when uncombined with any base or in excess (in which case alone it acts on litmus as an acid) is expelled by boiling for a few minutes, the trial of litmus before and after ebullition will determine whether the acid of the water is fixed or volatile.

Litmus already reddened by an acid will have its purple restored by an alkali, and thus it may also be used as a test for alkalies, but it is much less active in this respect than other direct alkaline tests.

2. *Red Cabbage* has been found by Mr. Watt[a] to furnish as delicate a test for acids as litmus, and to be still more sensible to alkalies. The natural colour of an infusion of this plant is blue, which is changed to red by acids, and to green by alkalies in very minute quantities. The colour is extracted simply by infusing the fresh leaves of the plant in warm water of about 120° for a few hours. The disadvantage of this liquor however is that it is peculiarly liable to change by putrefaction, when its properties as a test are lost. To preserve the cabbage for a length of time Mr. Watt advises to mince the leaves, spread them on paper, and dry them with a gentle heat, and then put them in closely corked bottles. When to be used, digest some of the leaves in a very dilute vitriolic acid which will give a red liquor; bring this to exact neutralization by chalk, so that the colour is a pure blue inclining neither to green nor purple, and then pour off the clear liquor and employ it. By adding a little alcohol it will keep good for some days.

3. *Brazil Wood.* When chips of this wood are infused in warm water they yield a red liquor which readily turns blue by alkalies, either caustic or carbonated It is also blued by the carbonated earths held in solution by carbonic acid, so that it is not an unequivocal test of alkalies till the earthy carbonats have been precipitated by boiling. Acids change to yellow the natural red of Brazil wood, and restore the red when changed by alkalies.

4. *Violets.* The delicate blue of the common scented violet is readily changed to green by alkalies, and this affords a delicate test for these substances. Syrup of violets is commonly used, as it is generally at hand, being used in medicine, but a tincture of the flower will answer as well.

5. *Turmeric.* This is a very delicate test for alkalies, and on the whole is perhaps the best. The natural colour of turmeric either in watery or spirituous infusion is yellow, which is changed to a brick or orange red by alkalies, caustic or carbonated, but not by carbonated alkaline earths, on which account it is preferable to Brazil wood. The pure earths, such as lime or barytic water, produce the same change, but these are never found in mineral waters.

6. *Rhubarb.* Infusion or tincture of rhubarb undergoes a similar change with turmeric, and is equally delicate.

7. *Sulphuric Acid.* A drop or two of concentrated sulphuric acid added to water that contains carbonic acid, free or in combination, causes the latter to escape with a pretty brisk effervescence, whereby the presence of this gasseous acid may be detected.

8. *Nitric and Oxymuriatic Acid.* A peculiar use attends the employment of these acids in the sulphuretted waters, as the sulphuretted hydrogen is decomposed by them; its hydrogen is absorbed, and the sulphur separated in its natural form. The theory of this operation has been fully explained under the article *Sulphuret*.

9. *Oxalic acid and Oxalat of Ammonia.* Oxalic acid is the most delicate test for lime that we are acquainted with, as it decomposes all the soluble calcareous salts, and precipitates with the lime as an insoluble oxalat. This precipitate when collected and dried, and strongly heated, blackens and melts, and the acid burning off, the lime is left white and carbonated. Oxalat of lime, though nearly insoluble in water, dissolves without difficulty in a moderate quantity of its own or any other acid, and hence in analysis oxalat of ammonia is often preferred as no excess of this salt can redissolve the precipitated oxalat of lime. On the other hand the ammonia should not exceed, otherwise it might give a false indication.

10. *Gallic Acid and Tincture of Galls.* This well known test of iron is peculiarly useful in the examination of mineral waters, as this is

[a] Phil. Trans. Vol. lxxviii.

almost the only metal ever met with. Where the iron is in very minute quantity, and the water somewhat acidulous, this test does not always produce a precipitate but only a slight reddening; but its action is much assisted by previously adding a few drops of any alkaline solution. The pure gallic acid, or the tincture, or the infusion of galls, act nearly equally well. Sometimes minute quantities of iron are well detected by suspending in the water a piece of the gall-nut for some hours.

11. *Prussiat of Potash and Lime.* The presence of iron in waters is equally well indicated by these prussiats, and if the prussiat of potash is properly prepared, it will only be precipitated by a metallic salt, so that manganese and copper when present will also be detected, the former giving a white, and the latter a red precipitate.

12. *Lime Water.* This is the common test for carbonic acid, as it produces a cloudiness and precipitate with water that contains any of this acid in whatever state of combination. It is however ambiguous, as it decomposes all the magnesian salts, and the magnesia which is thus separated being absolutely insoluble in water falls down as a white precipitate. The aluminous salts are decomposed in the same manner. Lime-water also produces a cloudiness with most of the sulphats, owing to the formation of selenite.

13. *Ammonia.* This alkali, when perfectly caustic, serves as a distinction between the salts of lime and those of magnesia, as it precipitates the earth from the latter class but not from the former. There are however two sources of error in the use of this alkali for this purpose, one is where carbonic acid is contained in the water, either free or united with magnesia, in which case the ammonia becomes partially carbonated, and then also decomposes the solutions of lime. The other is where any salt of alumine is contained, as ammonia will decompose these as well as the magnesian salts. The former source of error may be obviated by adding a few drops of nitric or muriatic acid to the water, and boiling it for a short time, by which the carbonic acid will be got rid of, and the earths will remain in solution. Then to distinguish and separate magnesia from alumine, redissolve both in muriatic acid, precipitate the solution by carbonated alkali, and then transfer the precipitate into cold acetous acid, by which the carbonated magnesia will be directly dissolved, and the alumine left.

14. *Carbonated Alkalies.* These are so far useful tests that they precipitate all the earths from their solutions. This is much hastened by boiling for a few minutes. Where carbonat of potash is used particular care should be taken of its purity as it generally contains silex.

15. *Muriated Alumine.* This test is proposed by Mr. Kirwan as indicative of carbonated magnesia in waters, and which cannot, like carbonated lime, be totally separated by ebullition, but remains till the whole liquid is evaporated. By adding muriated alumine to the boiled water a precipitate of carbonated alumine is found, if carbonated magnesia is present, but in no other case, unless there be an excess of alkali, which may easily be neutralized.

16. *Barytic Salts.* The nitrat, muriat, and acetite of barytes are all equally good tests of sulphuric acid in any combination. The power of this precipitant is greater than that of any other, except perhaps the salts of silver for muriatic acid. In applying the barytic salts the only care required is to neutralize any excess of alkali that there may be, with any acid but the sulphuric; and if the sulphureous acid be suspected, which is very rare, to free the water from it. The nitrat or acetite of barytes are sometimes preferable to the muriat, inasmuch as they introduce into the water to be examined no acid of a kind similar to any already contained. If any excess of alkali has caused a mixture of carbonat with sulphat of barytes, they may be readily separated by digestion with moderately dilute nitric or muriatic acid, which will dissolve the carbonat and leave the sulphat.

17. *Salts of Silver.* The salts of silver are the most delicate tests for muriatic acid in any combination, producing the precipitated muriat of silver or luna cornea, the composition of which is constant, and has been mentioned under silver. Any excess of alkali in the water should be previously saturated by pure nitric acid. The nitrat of silver is the salt commonly used as a test, but this as well as the acetite will also decompose the alkaline and earthy soluble salts with sulphuric acid, and a sulphat of silver will be formed, which it is not easy to distinguish by the eye from the muriat. This may be prevented either by previously getting rid of all sulphuric acid in the water by means of nitrat or acetite of barytes, after which all the precipitate of silver will be luna cornea; or else by employing a solution of sulphat of silver, which will then only act on the muriats. It should be observed however that nitrat of silver is a much more powerful precipitant of the

muriats than of the sulphats, so that if in any water where a barytic solution gives but a faint indication of sulphuric acid, an immediate precipitate is produced by nitrat of silver, we may be certain that it is the muriat of silver, and not the sulphat which falls down.

Acetite of silver has a particular use in decomposing the fixed alkaline muriats, as we are enabled thereby to distinguish the alkali more easily in the supernatant liquor; for by evaporating the latter to dryness, redissolving the remaining salt in alcohol, and gently evaporating the alcoholic solution to dryness, if it be acetite of potash, it will deliquesce, but if acetite of soda it will remain dry and effloresce.

All the salts of silver also give a black or dark brown precipitate with the sulphuretted waters, which is as delicate a test of sulphuretted hydrogen as any that we possess.

18. *Salts of Lead.* The nitrat and acetite of lead are the salts of this metal employed as tests. They will indicate the sulphuric, muriatic, and boracic acids, and sulphuretted hydrogen or sulphuretted alkali. The water being first freed from any excess of alkali by saturation with nitric acid, the addition of either of these salts of lead will decompose, and form a white precipitate with the acid of all the contained sulphats or muriats. But as sulphat of lead cannot by the eye be distinguished from the muriat, the precipitate should be digested in acetous or very dilute nitric acid or merely boiled in a good deal of distilled water, by any of which means the muriat will be dissolved, but the sulphat will be untouched. In these precipitates the acetite of lead is a more sensible test than the nitrat, but as the former when long kept will be partly decomposed by pure water, it should be assayed with water, and a little more acetous acid added if necessary.

Acetited lead is also decomposed by the carbonated earths and iron, so that the water should be boiled before this test is applied. This salt also produces an insoluble borat of lead when boracic acid is present in the water, which takes place in one or two rare instances. The borat of lead is distinguished from the sulphat of this metal by being soluble in nitric acid of 1.3. sp. gr. and from the muriat by being insoluble in water, or in weaker acids. But where boracic acid is suspected, Mr. Kirwan advises first to separate the sulphuric acid (if any) by acetited strontian, and the muriatic acid by acetited silver, neither of these acetites being decomposed by pure boracic acid.

Acetite of lead is also a very delicate test for the sulphurets, which it shews by turning to a deep brown or black. It is often applied by tracing characters on paper with acetite of lead, and immersing it in the sulphuretted water.

19. *Soap.* A solution of soap in distilled water, or in alcohol, is curdled by water containing any earthy salt. It is therefore a test of some use but not discriminative. The metallic salts produce the same effect, but the curd is then coloured.

20. *Tartareous Acid.* This acid is of use in distinguishing the salts with potash (with which it forms a precipitate of cream of tartar) from those of soda which it does not precipitate. It is necessary however that the solution of salt with the basis of potash (the sulphat or muriat for example) be much stronger than occurs in any mineral water in its natural state, so that it must be concentrated by evaporation.

21. *Nitro-Muriat of Platina.* This salt is still more discriminative between potash and the other alkalies than acid of tartar, and will produce a precipitate with a very weak solution of any salt with potash. It has not yet been much employed, but may often be of use.

22. *Alcohol.* This most useful reagent is applicable in a variety of ways in the analysis of mineral waters. As it dissolves some of the substances found in mineral waters, and leaves others untouched, it is a means of separating them into two classes, which saves considerable trouble in the further investigation. Those salts which it does not dissolve, it precipitates from their watery solution, but more or less completely according to the salt contained, and the strength of the alcohol, and, as a precipitant, it also assists in many decompositions. The great utility of *alcohol* to the analytical chemist has been already described under that article, and will be further mentioned in this.

The above are the principal tests or reagents employed. Several others might be enumerated which will easily suggest themselves to the practical chemist, and the theory of these respective operations will be better understood by consulting the articles themselves, to which we shall refer the reader to avoid repetition.

Before we describe the mode of analysis we may shortly recapitulate those foreign substances contained in mineral waters, for which there exists any appropriate *test* or chemical reagent by which its nature may be readily detected, and which therefore is to direct the operator in his further analysis. Where the precaution to be used in applying them has been mentioned, we shall not repeat it.

Oxygen Gas—Atmospheric Air. The presence of oxygen in water may be detected, according to Scheele, by filling a phial brimfull with it, dropping in a piece of newly crystallized sulphat of iron, and corking the bottle close. In a little time the salt will be dissolved, and in a few hours an ochery precipitate will be perceived, owing to the absorption of oxygen by the oxyd of iron of the salt, which then becomes insoluble.

Carbonic Acid.

(Test). Lime or strontian water—Litmus when in excess—Sulphuric acid—boiling.

Sulphuretted Hydrogen.

(Test). Nitric and oxymuriatic acids—Salts of lead and silver. A few globules of clean mercury allowed to remain for several hours in contact with the water, closely corked, will detect very minute quantities of it by being blackened at the surface. Silver leaf will answer as well.

Sulphureous Acid.

(Test). Mr. Kirwan gives as the only decisive test of this acid gas being held in solution in water, that when mixed with a tincture of roses reddened by an acid it renders this tincture colourless. This acid is also known by the smell. If perfectly pure it ought not to precipitate muriated barytes nor nitrated mercury, but it always does, which perhaps is owing to an inseparable admixture of sulphuric acid.

Mineral Acids uncombined.

(Test). Reddening litmus after the water has been boiled.

Boracic Acid.

(Test). Acetite of lead.

Carbonated Alkalies.

(Test). Turmeric—Rhubarb—Violets. If the change of colour does not take place after ebullition for several minutes, it shews that the alkali was ammonia.

Ammonia.

(Test). The presence of this alkali is partly distinguished in the way mentioned above, but more certainly by boiling a pretty large quantity of the water in a retort, carefully collecting the first ounce or two that distills, and moistening with this portion a piece of well-burnt lime, by which the ammoniacal smell will be distinctly perceived. The object of this distillation is to concentrate in a small compass all the ammonia of a larger quantity of liquid, which might be too dilute to indicate this alkali without this method.

Carbonats of Lime and Magnesia.

(Tests). Precipitated by ebullition, the former totally, the latter partially. After boiling, the magnesian carbonat remaining is indicated by muriat of alumine.

The Acid of the Sulphats.

(Tests). Salts of barytes and lead.—All the sulphats are also insoluble in alcohol, and precipitable by it from their watery solutions.

But sulphat of lime exceeds all the others in the ease with which it is thus precipitated.

The Acid of the Muriats.

(Test). Salts of Silver.—Alcohol unless very highly rectified dissolves a small quantity of muriat of soda, and does not precipitate the muriats with the ease with which it separates the sulphats.

Neutral Salts of Potash as distinguished from those of Soda.

(Tests). Tartareous acid—Nitro-muriat of Platina—Acetited barytes with the sulphats; and acetited silver with the muriats.

The Earth of the Calcareous Salts.

(Test). Oxalic acid or oxalat of ammonia.—Pure ammonia *not* precipitating it. Sulphuric acid, or better the alkaline sulphats, also decomposes the muriat of lime, and the resulting selenite is precipitated. This may be hastened by alcohol.

The earth of the Magnesian Salts.

(Tests). Pure ammonia—Lime-water.

The Earth of the Aluminous Salts.

(Test). Pure ammonia—Lime-water.

Silex.

(Test). This is chiefly suspected by its refusing to dissolve in any acid after the water has been once evaporated to dryness. It may be more certainly ascertained by melting it before the blow-pipe with three or four parts of dry carbonat of soda into a clear globule, which *then* will dissolve in water. Some of the waters that contain silex will *gelatinize* when evaporated almost to dryness, after which the silex will not redissolve by restoring the water which has been lost. This agrees with the known properties of silex in the analysis of minerals.

Salts of Iron.

(Tests). Galls—Prussiat of potash or lime. The carbonat of iron is precipitated totally by boiling.

Salts of Copper.

(Tests). Prussiat of potash—Ammonia—Metallic iron.

Manganese.

(Test). The brown colour of its oxyd, and its solubility in carbonat of potash.

Carbonaceous Matter.

(Test). Dissolves in concentrated sulphuric acid, giving it a clear brown colour.

Process of Analysis.

The first step in the examination of a mineral water, after the specific gravity, taste, smell, and physical properties have been noted, is to endeavour to form as accurate a notion as possible of the nature of its contents by the application of the several tests which have just been described. It is never necessary to apply all that have been enumerated, as many of the substances which they indicate are incompatible with others.

When this done the process of analysis may be begun, but it may be remarked that the mode must vary considerably according to the indication given by the tests, nor is it easy to give in a moderate compass the management to be pursued in every possible case. In fact a person should already be a skilful chemist, familiar with the practice of chemical operations, with the respective affinities of substances, and with their distinctive characters, and habitudes, before he undertakes any analysis.

For the description of these processes we must refer our readers to the respective articles, as it would be an useless repetition to give in this place any more than a general outline of them.

To determine the gaseous contents.

When any gasses are indicated by the proper tests, it is usual to begin by determining their nature and quantity.

If carbonic acid without any sulphuretted hydrogen be present, fill a narrow necked retort with the water taken at the spring head (having previously found the capacity of the neck of the vessel, which must of course be left empty) dip the beak under a graduated jar filled with mercury, and bring the water to ebullition. At this temperature all the carbonic acid (or nearly so) is disengaged, and collects in the mercury jar. When no more air-bubbles are given out (which must be distinguished from the mere motion of ebullition) remove the retort. The air standing above the mercury will then consist of the carbonic acid, together with any oxygen or azot that may be contained in the water, and all the atmospheric air that was contained in the neck of the retort, which last has been displaced and expelled by the hot aqueous vapour in its passage through. These may be separated either by lime-water, or by caustic or semicaustic alkali, such as common pearlash, which absorb the carbonic acid only, and consequently indicate its quantity in the portion of water that was employed.

After this, the residue may be examined to find the relative quantities of oxygen and azot in the methods already described under the article *Eudiometer*, and if more of either appears than will be accounted for by the air in the neck of the retort, this excess will belong to the water under examination. The corrections and precautions requisite in the estimation of the bulk and weight of airs, relative to temperature and pressure, should be carefully remembered, and will be found under the article *Gas*.

In expelling air from water by ebullition as little space as possible should remain in the neck and conducting tube of the apparatus, on which account a glass globe, with a short and moderately wide neck, and a bent tube fitted thereto is preferable to a retort, for the neck of the latter is purposely made wide and roomy, this being an advantage in common distillation. A little water must of course distill over during the boiling, which will rise through the mercury along with the gas, but this will not materially interfere with the accuracy of the experiment.

As a mercurial pneumatic apparatus is not always at hand, the gas may be received through water, and the absorption of the gas by this fluid may be in a great degree prevented by employing it very hot, for at a high temperature water will hardly absorb fixed air. This however is not quite so accurate as with the mercurial apparatus.

Some chemists have endeavoured to estimate the quantity of carbonic acid without any ebullition and expulsion of the gas, simply by adding lime-water to the mineral-water fresh from the spring, and collecting, drying and weighing the carbonat of lime thus produced. But this method is extremely fallacious in most cases, for the lime-water will also precipitate all the carbonat of lime held in solution by the carbonic acid, and the carbonat of magnesia, and besides will decompose the other magnesian salts, and cause their earth to precipitate. So that this method is inadmissible in by far the greater number of actual cases, and can only apply where the water contains no other ingredients than carbonic acid, and salts with the bases of lime or alkali.

Where the water contains sulphurous acid gas with or without carbonic acid, Mr. Kirwan recommends to expel both by ebullition in the usual way, receiving them over mercury; to add solution of pearl-ash to absorb both, then gently to evaporate the alkaline solution nearly to dryness, and to expose it for some days to the air, by which the sulphite of potash obtained by union of the sulphurous acid with the alkali will be converted into sulphat. This being ob-

tained separate, the quantity of sulphurous acid may be found, estimating that 100 grains of sulphat of potash contain 45 of sulphuric acid, equal to 15 of sulphur, equal to 30 grs. or 42.72 cubic inches of sulphurous acid gas.

Instead of obtaining the sulphat of potash separate, which it is difficult to do exactly, the alkaline solution, after the sulphite has become sulphat, may be saturated with muriatic acid, and the quantity of sulphuric acid then estimated by muriat of barytes.

The accurate estimation of sulphuretted hydrogen is very difficult, particularly when mixed with carbonic acid gas. The sulphuretted hydrogen may indeed be expelled almost entirely by boiling, but when received over mercury it is partly decomposed by this metal, and when by water it is partly absorbed by it, though this last inconvenience is in a good measure prevented by warming the water.

There are two ways of estimating it. One of them is the following: boil the water and receive the gasses over mercury in the usual way. These may consist of carbonic acid, sulphuretted hydrogen and azot, but not oxygen, this being incompatible with susphuretted hydrogen. It is necessary in order to obtain the carbonic acid pure that the sulphuretted hydrogen be first separated, for the alkalies and the alkaline earths absorb both. For this, Mr. Kirwan advises, first to displace any mercury remaining in the jar by dipping it a little way in hot water, whereby the mercury will fall down and the water take its place. Then dip the jar into a small vessel full of moderately strong nitrous acid, by which the acid will mix with the water and come in contact with the gasses, and absorb very speedily or decompose the sulphuret, and leave the carbonic acid and azot, which last may afterwards be separated by an alkali.

But as all the sulphuretted hydrogen cannot be expelled undecomposed from the water, the above method is quite accurate only for the other gasses. Mr. Henry suggests as an improvement to the above method, instead of using nitrous acid, to throw up oxymuriatic acid gas to the mixed gasses standing over water, till the jar is filled, closing the jar with a ground stopper, and allowing the mixture to remain for twenty-four hours. Then on opening the jar under water, a quantity of this fluid will rush in to fill the vacuum produced by the decomposition of the sulphuretted hydrogen, and standing about half an hour without agitation, the excess of oxymuriatic acid will be absorbed, and only the carbonic acid and azot will remain. In this process the oxymuriatic acid gas should be quite pure, such as is obtained from oxymuriat of potash and muriatic acid, and equal in bulk to the other gas, but the required purity of this gas is certainly an objection.

The mere quantity of sulphuretted hydrogen

[b] Essay on Mineral Waters, p. 194.

turn up the mouth of the bottle and blow out the residuary air. If the hepatic smell continues in the water, repeat the addition of nitrous air as above till the smell is destroyed. Then add a few drops of nitrous acid to prevent the precipitation of the earths, heat the water to 150° for an hour and filter it. The excess of weight which the dried filter will gain over its original weight will indicate the weight of sulphur set free by this process, from which the quantity of sulphuretted hydrogen may be estimated, allowing 3.33 cubic inches of the gas for every grain of sulphur.

But under the article *sulphuretted hydrogen* we have shewn the great diversity in the estimation of its composition by two very able chemists; a diversity which perhaps may arise from some error in the mode of computation, or with equal probability may depend on a real variation in the proportion of the constituents of this gas according to the mode in which it is procured or other circumstances. Hence we can have but little reason to trust implicitly in the mode of estimating quantities of sulphuretted hydrogen by the actual weight of sulphur produced, especially in such dilute solutions of this gas as the native sulphureous waters are, of which some of the strongest, such as that of Harrogate, contain no more than about $\frac{1}{12}$ of their bulk.

Estimation of the Earthy and Metallic Carbonats.

These when they occur should next be examined. They are, carbonat of magnesia, of lime, of iron, and sometimes of alumine. Of these the three latter are totally precipitable by ebullition for a quarter of an hour, but the former only partially, and is not totally separated till the water is evaporated to a very small bulk. A given quantity therefore of the water (which may be the portion from which the gasses have been separated by ebullition) should first be boiled for a quarter of an hour, and after standing for a time the earthy sediment may be collected, edulcorated and dried. Then add dilute cold muriatic acid, which can redissolve only lime, magnesia, and oxyd of iron, and leave the alumine. Add caustic ammonia by drops to the solution, which will separate first the oxyd of iron coloured, and then the magnesia nearly white, whilst the lime will remain. If no magnesia is detected, nothing further is necessary than to ascertain the actual quantities of the carbonats of lime, iron and alumine, the latter being left undissolved by the muriatic acid, and, of the two former, the iron alone being precipitated by ammonia; and thus each substance is obtained separate, and may be brought to their original state of carbonat by subsequent processes which will easily suggest themselves. But if the sediment deposited by boiling the water contains any carbonat of magnesia, it is a proof that some of the same earthy salt remains in solution, which may also be further confirmed by the boiled water giving a precipitate with muriated alumine. In this case a considerable quantity of the water should be boiled down uninterruptedly to the bulk of a few ounces and allowed to cool. Then collect the entire sediment, edulcorate it and dry it. It now contains all the earthy and metallic carbonats, but is perhaps mixed with some selenite, which is deposited towards the end of the evaporation. Cold dilute muriatic acid will then redissolve the carbonats of lime, magnesia, and iron, and leave the selenite as well as the alumine. The muriatic solution then contains all and only the lime, magnesia, and oxyd of iron which existed in the water in the state of carbonat, these Mr. Kirwan proposes to separate in the following way. Add ammonia to the solution to separate the magnesia and iron and leave the lime. Redissolve the magnesia and iron in muriatic acid, and precipitate both by carbonat of soda, and expose the precipitate while moist to the air for a few days. Distilled vinegar applied without heat will then redissolve only the carbonat of magnesia and leave the iron. The reason of this second solution of the magnesia and iron is in order to carbonate the magnesia by precipitation with a carbonated alkali, for when this earth is pure it is not easily soluble in acids, and it is by the easy solubility of its carbonat that it is to be separated from the oxyd of iron in this instance.

The above method of separating the earths and iron is inaccurate, inasmuch as it is fully ascertained that ammonia will never separate the whole of the magnesia from its acid solutions, and therefore though it is extremely useful as a test to assay any liquor for magnesia, it cannot be depended on to give the actual quantity of this earth. The difficulties and the best methods, at present known of separating lime and magnesia, are mentioned under the articles *Sulphat* (p. 389), *Muriat* (p. 1:3), and *Lime*, (p. 41). They are, either by converting both into sulphats and calcining the mixture, which will render the sulphat of magnesia alone soluble in cold water; or by converting them into muriats and heating them nearly to redness, by which the muriatic acid is driven off from the magnesia alone (whereby it is rendered insolu-

ble in water) and not from the lime. In either case however the presence of iron would prove embarrassing, and in the latter much of it would be volatilized with the muriatic acid, and therefore we should advise, first to separate it from the muriatic solution by prussic acid or succinat of ammonia, then to throw down the earths by carbonat of soda, to edulcorate, and redissolve them either in sulphuric or muriatic acid, according to the method of separation adopted. On the whole we should prefer the sulphuric acid.

Estimation of the remaining Substances.

We have now separated from the water, and estimated all the gasses and all the earths and oxyd of iron held in solution by carbonic acid. The water therefore now can only contain fixed salts, with alkaline, earthy, or metallic bases, silex, and extractive or carbonaceous matter. If the presence of carbonat of magnesia has made it necessary to evaporate nearly to dryness, and if any sulphat of lime has precipitated, it should be added to the remaining water after the magnesian carbonat has been abstracted.

It should be premised that if the tests indicated any ammonia in the water, it should first be separated by distillation in the way already mentioned.

The further operations to be performed upon the water must be regulated in a good measure by the contents pointed out by the different reagents. If, for example, no earthy salt now remains, but both sulphuric and muriatic acid are indicated, and at the same time no excess of acid or alkali exists, we may conclude that all the remaining saline ingredients are sulphat and muriat of soda (potash being extremely rare) and it then becomes a question which is the best mode of estimating their respective quantities. If at the same time an excess of alkali exists, we may conclude that together with these salts carbonat of soda is contained.

The way of ascertaining the fixed salts of any mineral water, which till lately has been the most frequent, is that recommended by Bergman, and which indeed would first suggest itself, namely, to evaporate the liquor till the least soluble salt began to crystallize, and then by a judicious alternation of gradual warmth, and of cooling, to endeavour to obtain the distinct crystals of each salt to the last drop of the solution.

But though evaporation and crystallization are extremely useful and indeed almost indispensible to satisfy the chemist as to the real nature of the saline and other contents, it has long been found impracticable even by the most skilful operators, perfectly to separate any two salts in this manner. This is caused partly by the increased solubility which two salts give to each other when held in solution in the same liquid; partly by the change in the natural form of crystals which is sometimes produced; and partly by the extreme difficulty of picking out crystals which grow more and more minute in proportion as the bulk of the solution is lessened by the repeated abstraction of its contents. The great difficulty too in retaining exactly the same proportion of water of crystallization is another objection to this mode, though this might be remedied by exposing the salt, when obtained, to such a degree of heat as will produce an uniform desiccation. The best analysts therefore have nearly abandoned the attempt at estimating actual quantities of saline ingredients (where accuracy is required) by crystallization, except where no other mode can well be adopted, as is the case with the nitrous salts. The method commonly preferred is to decompose these salts in such a manner as to produce an insoluble precipitate with one or other of their ingredients, and from the weight of this to estimate (from previously known data) the quantity of the decomposed salt. The salts with alkaline bases are estimated by the precipitate which their acids form with earthy or metallic bases; the sulphats, for example, are analysed by salts of barytes or lead; the muriats, by salts of silver; the borats, by lead, &c. The salts with earthy bases are estimated by separating either their earth (generally by a carbonated alkali) or their acid, and where it can be done it is more satisfactory to employ both.

Another process is used to ascertain quantities of unneutralized acid or alkali existing in any water, as of soda for example, or rather its carbonat, which is a frequent ingredient in many hot mineral waters. This was first used we believe, by Dr. Black, in his analysis of the Iceland hot waters,[c] and it consists in exactly saturating the alkali with a portion of any acid (or *vice versa*, the acid with an alkali) whose strength has previously been determined by trials upon known quantities of the same acid or alkali. Thus in the above example a very dilute vitriolic acid was used, whose power of saturating soda had been previously tried, and the delicate tests of litmus and violet were employed to hit the precise point of saturation.

[c] Edinb. Transact. Vol. iii.

We shall add in the appendix a table of a few of the most important corresponding quantities of precipitates with salts which are the most frequently used in analysis.

To proceed with the examination of the de-aerated water freed from the earthy carbonats.

Evaporate a given quantity (which with most waters should not be less than about a gallon) with a heat which, to save time, may be that of boiling till towards the end, when a more gentle heat must be used to avoid decomposing or volatilizing any part of the ingredients. The evaporation may be carried on in almost any clean vessel, especially where no excess of acid exists in the water, but when only a few ounces are left, it should be transferred to a glass or silver dish, with every thing that may have subsided in the boiling, and brought by a slow fire to perfect dryness. The further management of this residue depends on the nature of its contents. If previous experiments have shewn that no earthy or metallic salt exists in the boiled water, it will be sufficient to re-dissolve it in a little warm distilled water, by which any silex that may be contained will be left behind; and the latter may be still further known by its insolubility in muriatic acid, and by fusion with soda.

The aqueous solution can then contain only any acid or alkali which may exist in excess, and any neutral salts with alkaline bases. Then saturate an aliquot part of the solution and assay it with tartareous acid, which in this concentrated state, will precipitate cream of tartar if potash exists. If none is found (which is by far the most common) the alkali must then be soda, and the nature of the acids being also found, the respective quantities of the neutral salts may easily be inferred in the way above mentioned. Thus if the water indicate sulphuric and muriatic acid, and an excess of soda (which is the case with the Carlsbad water, analysed by Klaproth) the alkali is first to be saturated with sulphuric acid of a known strength, and the whole sulphat decomposed by acetite of barytes. Then, calculate the equivalent quantity of sulphat of soda to the sulphat of barytes obtained, subtract that portion of it which is formed by the sulphuric acid employed to saturate the uncombined soda, the residue is the portion of sulphat of soda natural to the water. The muriat of soda is then indicated by nitrat of silver, allowing 100 parts of luna cornea to be equivalent to 428.25 parts of common salt.

The excess of fixed acid where it exists is almost always the sulphuric, but it has hitherto been only found in company with alum, or other sulphuric salts, that have a natural excess of acid. If it should ever be found only associated with alkaline sulphats or muriats, this excess may be found by adding barytic water merely to saturation, and no further, which will then only indicate the excess of acid.

But the greater number of mineral waters contain some earthy salt, the acid of which is fixed, so that it remains in solution after boiling and concentration. This acid is hardly ever any other than the sulphuric and muriatic, and the earth is most commonly lime or magnesia. Therefore only four earthy salts may be expected (not all together indeed, as they would decompose each other) namely, sulphat of lime, muriat of lime, sulphat of magnesia, and muriat of magnesia. Of these salts the sulphats are insoluble in alcohol, but the muriats are extremely soluble. This therefore affords a very useful means of separating some of them. For this purpose put the entire dry residue in a phial, pour on it about five or six parts of highly rectified alcohol, and let the mixture remain for some hours with frequent agitation. The alcoholic solution can then contain only muriat of lime and magnesia, if the alcohol has been highly rectified; if not it may also dissolve a little muriat of soda. The method of separating and estimating a mixed muriat of lime and magnesia, has already been mentioned. The residue which is not dissolved by the alcohol may contain the sulphats of lime and magnesia, of which the latter salt is easily soluble in water, but the former with great difficulty unless assisted by an acid. The mode of separating these has also been mentioned.

With regard to sulphat of lime which is so common an ingredient in waters, it is of use to know that when it is in solution in as small a bulk of water as possible, and especially when assisted by an excess of acid, it may be totally precipitated by adding a much smaller quantity of alcohol than will separate any other of the sulphats, as has been mentioned under the article *Sulphat of Lime*.

Sulphat of iron is now and then found in mineral waters, though much more rarely than might be expected from the frequency of pyrites in most parts of the earth. When a water remains chalybeate after boiling, we may pretty safely infer that the iron is united to the sulphuric acid. But as sulphat of iron is partly decomposed by exposure to air, the residue, after the water has been evaporated to dryness, contains both sulphat of iron and some uncombined oxyd of this metal, and the sulphat is then

partly changed to the red ſulphat, or that in which the iron is in its higher ſtate of oxygenation. It is not poſſible therefore to procure with any accuracy ſmall quantities of ſulphat of iron from any mineral water by evaporation, or any other known way, ſo that the only method ſeems to be, to obtain the whole of the oxyd of iron ſeparate from every other ingredient, to bring it to a known ſtate of oxygenation, and then to eſtimate its equivalent quantity of green or cryſtallized ſulphat.

The methods in which this may be done will be ſuggeſted by comparing the beſt analyſes of iron. Pruſſiat of potaſh ſeems on the whole to be preferable where this ſalt is properly prepared. Muriat of iron has not yet been found. If uncombined with the ſulphat, it might be diſcovered by not depoſiting its oxyd during evaporation, and by being ſoluble in alcohol; and even if both ſalts of iron were preſent, and no earthy muriat, it might be detected by evaporation, by treatment with alcohol, which would then diſſolve both ſalts of iron (the green ſulphat being converted by the boiling into the red, which is ſoluble in alcohol) and by ſulphat of ſilver added to the alcoholic ſolution. But where other muriats ſoluble in alcohol alſo exiſted, it would require a complicated proceſs to detect muriat of iron combined with the ſulphat.

In giving the reſults of the analyſis of a mineral water, the preſent ſtate of chemical knowledge demands that the particulars of the proceſs (at leaſt the outlines) ſhould be given, together with the data from which the inferences of quantities are eſtimated. It is alſo eſſential for the operator to preſerve ſome uniform method of drying his ſalts and precipitates, and the temperatures at which this is performed ſhould never be omitted. A greater attention to this point would enable us often to reconcile the ſtatements of chemiſts of known fidelity, which now differ widely, and might lead to many important diſcoveries in the complicated and difficult ſubject of chemical affinity.

WATER OF THE SEA.

The analyſis of ſea-water and the chemical uſes to which it is applied, will be found under the articles MURIAT, p. 124, and SULPHAT, p. 388, of this volume.

WATER OF CRYSTALLIZATION is that portion of water which moſt ſalts retain when in their cryſtallized form. The relative quantity of this water to the ſaline part varies extremely. In ſome it is not more than 2 or 3 per cent. in others it forms more than half the cryſtal. In the former caſe the ſalts are hard and decrepitate when briſkly heated; in the latter they liqueſy. The quantity of this water often varies in the ſame ſalt much more than would be expected from the ſimilarity in form and appearance, which will partly account for the great difference which we find in the eſtimation of their contents, as given by different chemical writers.

WAX. *La Cire.* Fr. *Wachs.* Germ.

There are two or three ſubſtances which reſemble each other ſo cloſely as to have received the name of Wax. The firſt, and by far the moſt important is *Bees Wax*, which is conſumed in ſuch vaſt quantities for giving light, and is alſo uſed for a variety of other purpoſes. Another kind of wax is the myrtle wax, which is extracted pretty largely in Louiſiana and ſome other parts of America, from the *Myrica Cerifera.* Another ſubſtance very ſimilar to wax is the *Pe La* of the Chineſe, the product of an inſect, the exact ſpecies of which is not known; and the white matter which yields the LACCIC *Acid* has alſo a ſtrong reſemblance to wax.

The properties which all theſe ſubſtances have in common are, fuſibility at a moderate heat; when kindled, burning with much flame; inſolubility in water, ſolubility in alkalies, and alſo in alcohol and ether. In theſe two latter properties all the ſpecies of wax differ from the concrete oils, with which in other reſpects they have a very ſtrong reſemblance.

BEES WAX is the ſubſtance, excreted from the body of the bee, of which theſe inſects conſtruct their cells, both thoſe for containing honey and for the lodgment of their young. It is collected for the uſe of man wherever bees are kept. A young hive will yield at the end of the ſeaſon about a pound of wax; and an old hive about twice as much. The colour of wax when freſh from the bee is nearly white, but it ſoon grows conſiderably yellow in the hive, or if very old is of a dark brown. The origin of the wax we ſhall mention afterwards. The fineſt wax is found to be made in dry, heathy, or hilly countries, but it is decidedly inferior in parts full of vineyards. The loaves of common bees wax are made immediately from the honeycomb, by a ſlight preparation. The combs are firſt emptied of all the honey that can be collected by the preſs, and are then either ſoaked for ſome days in clear water to extract all the remaining honey, or in ſome parts they are broken down and ſpread on a ſheet in the neighbourhood of the hives, and in time the bees ſuck out all the honey that is left, and reduce

the wax to ſmall pieces like bran. The whole of the wax is then melted in a clean copper with boiling water, and ſtrained by a preſs through cloth bags, to free it from every impurity. It is then caſt into cakes, in which form it is received by the wax-refiners.

The wax of theſe cakes, which is the ordinary bees wax of the ſhops, is a pale yellow ſubſtance, of an agreeable honey-like ſmell, ſoft, and ſomewhat unctuous to the touch, but without ſticking to the fingers, in winter becoming conſiderably hard and tough, and melting at about 142°.

This yellow colour and the ſmell of wax are entirely taken away by expoſing it, when divided into thin laminæ, to the united action of the light and air, and by this means it becomes perfectly white, ſcentleſs, ſomewhat harder and leſs greaſy to the touch, and in this ſtate it is employed for candles and many other purpoſes. The proceſs of bleaching wax is the following:[a] The yellow wax is firſt broken into ſmall pieces and melted in a copper cauldron along with a very little water, juſt ſufficient to prevent the wax from burning, for it is of importance to uſe no more heat than is neceſſary. The plug of the copper is then drawn, and the melted wax and water fall together into a veſſel below, where it is covered with a thick cloth to keep in the heat for ſome time, that the water and impurities may ſettle. The clear melted wax is then ſuffered to flow into a veſſel with the bottom full of ſmall holes about the ſize of a grain of wheat, whence it falls in ſmall ſtreams upon a cylinder kept conſtantly revolving over water in which it partly dips, by which the wax is immediately cooled, and at the ſame time drawn out into thin ſhreds or ribbands. Theſe ſhreds are then ſpread upon cloths ſtretched on large frames, which are ſupported a foot or two from the ground, and after expoſure to the ſun and air for ſeveral days, with frequent turning, their yellow colour nearly diſappears. The half-bleached wax is then heaped up in a ſolid maſs, and allowed to remain for a month or ſix weeks, after which, to give it compleat whiteneſs, it is re-melted, and ribbanded, and bleached as before, till it is entirely void of colour and ſmell. Some manufacturers add in the re-melting either alum or cream of tartar, or ſometimes milk, all of which are ſuppoſed to increaſe the whiteneſs and ſolidity of the wax.

Inſtead of ſpreading the ribbands of wax on cloths, ſome employ a broad courſe of bricks laid evenly, which are frequently watered to prevent the wax from melting by the heat of the ſun abſorbed by the bricks.

Wax is frequently adulterated by tallow, ſuet, or animal fat of ſome kind or other. This gives the mixture a greater fuſibility, ſo that when ribbanded and expoſed to a hot ſun it is extremely apt to cake. It alſo takes away from it the ſemi-tranſparency, which is a diſtinguiſhing property of pure bleached wax; for though fine tallow is full as white as wax, it is always a dead opake white. The adulteration may alſo be detected by boiling alcohol, which diſſolves wax but not tallow.

Bleached wax burns with a very pure white light, and gives no offenſive ſmell, and very little ſmoke compared with tallow. Being leſs fuſible than tallow it requires a ſmaller wick. Bleached wax melts at about 15° or 7° higher than the unbleached. Its ſpecific gravity is leſs than that of water, being about .96.

Alcohol has no ſenſible action on wax when cold, but on boiling this fluid, it diſſolves rather leſs than $\frac{1}{20}$ of its weight of wax, the greater part of which ſeparates when cold in the form of white bulky flocculi, and what little remains in ſolution is entirely precipitated by water.[b]

Sulphuric ether diſſolves wax when a little heated, and much more copiouſly than alcohol does, but the greater part is alſo ſeparated by cooling and the remainder by water.

When wax is boiled in cauſtic potaſh, the fluid becomes turbid, but after a time moſt of the wax riſes to the ſurface, and in a flocculent form. The clear alkaline liquor then holds in ſolution a portion of the wax, which may be ſeparated by an acid, and the part that remains on the ſurface is ſo far ſaponified as to have loſt its inflammability, and to be as ſoluble in pure water as white ſoap is, and again precipitable by acids nearly in its original form, with its inflammability reſtored. Pure ammonia acts nearly as the fixed alkalies, but the reſulting ſaponaceous ſcum is leſs ſoluble in water.

If wax is diſtilled with a heat greater than that of boiling water it is decompoſed.[c] A ſmall quantity of water firſt riſes, which is followed by a very penetrating volatile acid (probably a modification of the acetous) accompanied with a little very fluid and odoriferous oil. As the diſtillation advances the acid becomes ſtronger, and the oil much more copious and thicker, till at laſt its conſiſtence is ſuch as to become ſolid in the receiver, when it is called *Butter of Wax*. When the heat is raiſed to low redneſs, and every thing volatile has come over,

[a] Encycl. Arts et Met.. [b] Boſtock in Phil. Journ. Vol. iv. p. 184. [c] Macquer's Dict.

a small quantity of coal is left behind. The oil and butter of wax, if again distilled in a gentle heat, become more and more fluid, and at the same time acquire a greater solubility in spirit of wine, and this oil never hardens by keeping.

Wax is soluble abundantly in the fixed oils, and when melted with them an uniform mass is produced, whatever be the proportions of each, the consistence of which is intermediate between the two. Oil and wax sometimes with spermaceti, form the basis of most of the cerates and ointments used in pharmacy.

The essential oils dissolve wax but sparingly.

The action of the acids upon yellow wax has been examined in a series of experiments by Beckman,[d] particularly with a view to their bleaching power. The same subject has also been followed by Sennebier,[e] who has added some remarks on the effect of light and other supposed decolouring agents.

The operation of light was thus shewn: some yellow wax was melted and thinly spread on a plate of glass; a similar plate was laid upon it when hot, and the edges of the plates were closed with sealing wax. The bees-wax therefore was deprived of the access of air, and it was placed in the sun, and exposed to its light for four or five hours daily. Another quantity of wax was inclosed between plates in a similar manner, but kept in the dark. In two days the wax kept in the sun began to bleach, and in a month's time the whole, where it did not exceed two lines ($\frac{1}{6}$ of an inch) in thickness, was quite white, whilst no change whatever took place in that which was kept in darkness.

If thin shavings of wax are immersed in either of the three mineral acids,[f] a little dilute, in a few hours the yellow colour disappears, and the wax is rendered partly white, partly pellucid. No further change takes place, nor is the colour of the acid at all altered (unless heat be applied) for many weeks. The bits of wax are however much hardened by remaining in the acid, so as to rattle when shaken against the sides of the glass, and by brisk agitation they may be broken down into very minute white flocculi. This change takes place much the most rapidly in the nitric acid, or in the nitro-muriatic, and it is compleatly effected in an hour or two. It also happens when wax is melted in nitric acid, though less rapidly. This circumstance led the author of these experiments to expect that something might be done in the large way in bleaching wax by nitric acid, but this hope proved fallacious, for on removing the wax from the acid and melting it in water, (which is necessary to extract the acid) the wax resumes a yellow colour, and the water also becomes of a high brown yellow. By repeatedly melting the wax in water (without any additional acid) it becomes more and more yellow, and at the same time grows harder and much more fusible than at first.

Neither is the vapour of burning sulphur, which so speedily bleaches silk and many other substances, more successful in depriving wax of its colour.

The effect of caustic alkali upon wax has been already mentioned. When yellow wax has long been swimming in a solution of carbonat of potash, it becomes grey, and this colour is entirely changed to a milk-white by subsequent digestion in nitric acid, and the wax resumes its whiteness.

Professor Beckman then tried the whitening effect of fuller's earth, or some similar substance, being led to use it from the known power which it has in whitening and purifying tartar. Some yellow wax was melted, and a quantity of this earth finely powdered was sprinkled in. The wax was then melted out, and being fused in water it appeared grey, like wax half-bleached in the common way, which the author supposes would save much time in the whole process.

A few words may be added as to the origin of wax. It is usually supposed that the wax is the *pollen* of flowers, which the bees visibly collect on their thighs, and afterwards elaborate in some unknown way. The great difference between wax and this matter which the bees collect, has however been long remarked. When examined by the microscope this little mass of pollen is obviously composed of a number of hard grains compressed together, and if it is laid on a hot plate, it does not melt as wax would do, but smokes, dries, and is reduced to a coal, and if kindled it burns without melting.

Some late very curious experiments of Huber,[g] one of the most celebrated apiarists in Europe, has further shewn that the pollen has no share whatever in the formation of wax, but that this latter substance is produced indiscriminately from honey, sugar, or any other saccharine matter which serves as food for the bees. The details of these experiments hardly belong to chemical subjects; it is sufficient to mention that they were performed by confining separate

[d] Nov. Comment. Soc. Reg. Gotting. Vol. v. for 1774. [e] Journ. de Phys. Tom. xxxviii. for 1791. [f] Beckman. [g] Journ. de Phys. Tom. lviii.

ſwarms of bees within their hives, and feeding one with honey, another with muſcovado ſugar, another with treacle, another with refined ſugar, in all of which abundance of fine wax was produced: and on the other hand, by feeding another hive only with pollen and fruits, no wax whatever was formed, though the bees remained for a week in their confinement. Other obſervations and experiments by this ingenious naturaliſt ſtill further explain this ſubject, by ſhewing what is the real uſe of the pollen, namely, to afford ſuſtenance for the larva of the bee the moment it is hatched.

The Myrtle Wax is a concrete ſubſtance moderately hard, nearly of the conſiſtence of bees-wax, and of a dingy green colour: it is contained in abundance in the berries of the *Myrica latifolia*, a fragrant buſhy ſhrub with leaves like the myrtle, which grows abundantly in many parts of North America: it is alſo procured from another ſpecies of the ſame genus, the *Myrica Gale* which is common in boggy moſſes in ſeveral counties of England.

A very large quantity of the myrtle wax is extracted from this ſhrub in Louiſiana, by collecting the berries, boiling them with water, and bruiſing them at the ſame time, by which the wax melts out and riſes to the top as a thick oily ſcum, which is eaſily ſeparated. The berries yield about a fourth of their weight of this wax.[h] They contain alſo, according to M. Cadet, a conſiderable quantity of gallic acid.

This wax has been examined chemically both by the above-mentioned chemiſt and by Dr. Boſtock, and it is found to reſemble bees-wax ſo cloſely in the moſt important properties, that they may be claſſed under the ſame genus of chemical bodies. In ſome reſpects however the myrtle wax differs from that of the bee. Its ſpecific gravity is 1.015, ſo that it ſinks in water. It melts at 109°, and when kindled it burns with a clear white flame, and an agreeable aromatic odour, and produces little ſmoke. With alcohol, ether, and the alkalies, its habitudes cloſely reſemble thoſe of bees wax, only it appears to be a little more ſoluble in each of theſe menſtrua. The acids have, when cold, as little effect on the myrtle wax as on that of the bee, and the former is not entirely bleached by digeſtion with nitric acid, but only rendered of a pale yellow. Cauſtic potaſh however in diſſolving it whitens it compleatly. No attempts have yet been made to bleach it in the large way by expoſure to the ſun and air.

The myrtle wax is uſed largely in ſome parts of America, as a material for candles, and on the whole it appears worthy of further attention.

WEIGHTS. See the Appendix.

WELD. In addition to what has been ſaid on the uſe of this plant under the article Dyeing, we may add that the fine delicate yellow which it gives is much employed by the paper ſtainers in this town, and is ſold in the form of hard lumps, conſiſting chiefly of chalk ſaturated with the colouring matter.

The following is given by Meſſrs. Collard and Fraſer as an improved proceſs.[a] Diffuſe any quantity of fine whiting in boiling water, add thereto one ounce of alum for every pound of whiting, which will cauſe a briſk efferveſcence, and ſtir theſe materials well together till all diſengagement of gas has ceaſed. On the other hand, boil in a ſeparate veſſel ſome weld with water juſt enough to cover it, for fifteen minutes, filter the yellow decoction, and then mix it with the whiting and alumine in ſuch proportions as that the earths may appear to be ſaturated with the colouring matter. Then let the mixture remain a day at reſt, and at the bottom will be the precipitated earth firmly united with the colour, and of a fine yellow tinge, which may be conveniently dried on chalk-ſtones.

The weld yellow is a water colour, and is never mixed with oil.

WELDING. Welding is that intimate union produced between the ſurfaces of two pieces of malleable metal when heated almoſt to fuſion and hammered. This union is ſo ſtrong that when two bars of metal are properly welded, the place of junction is as ſtrong relatively to its thickneſs as any other part of the bar. Only two metals are capable of firm union by welding, namely *platina* and *iron*, (which ſee).

WELTER's TUBE. See Appendix of Apparatus.

WERNERITE.

Its colour is intermediate between piſtachia-green and Iſabella-yellow. It occurs cryſtallized in rectangular tetrahedral priſms, terminated by obtuſe tetrahedral pyramids: ſometimes the lateral edges are truncated, forming an octohedral priſm. The cryſtals are ſmall, and laterally aggregated. It is more or leſs ſhining with a luſtre between greaſy and pearly: its fracture is curved lamellar in two directions, paſſing into uneven. It is tranſlucent, and ſomewhat inferior in hardneſs to felſpar. Sp. gr. 3.6.

Before the blow-pipe it intumeſces, and melts

[h] Cadet, in An. Chim. Tom. xliv.

[a] Phil. Mag. Vol. xiii.

easily into a white opake enamel. It occurs in the iron mines of Northo in Sweden, and near Arendahl in Norway.

WETZCHIEFER. See THONSCHIEFER.

WHINSTONE. See BASALT and TRAP.

WHITE COPPER. See COPPER. (*Alloys of*).

WHITE LEAD, or *Ceruſſe*. See LEAD.

WINE.

Under the articles *Fermentation*, *Brandy*, *Alcohol* and *Tartar*, we have already deſcribed (ſufficiently at length for a manufacture not uſed in this country) the method of converting the grape juice into wine, and of procuring ardent ſpirit from the latter by diſtillation; we ſhall therefore in this place only mention the analyſis of wine as given by M. Chaptal in his elegant and valuable memoirs on the culture and produce of the vine*.

All wines contain an acid, alcohol, tartar, extract, aroma, and a colouring matter. The preſence and nature of each of theſe principles may be aſcertained in the following way.

1. *Acid*. All wines, even the ſofteſt and mildeſt, redden litmus, and therefore contain an acid. This abounds however chiefly in the thin wines of wet and cold climates, where the grape juice or *muſt* contains but a ſmall portion of ſugar. When wine has been boiled to extract the brandy, the liquor that remains in the ſtill, and is thrown away as uſeleſs, is a ſour nauſeous fluid with an acrid and burnt flavour. When filtered and allowed to remain at reſt for a time, it depoſits a good deal of extractive matter, becomes covered with mould, and then contains a notable quantity of acetous acid, which may be ſeparated by diſtillation. The acid is however not entirely acetous, at leaſt not till after ſtanding a conſiderable time, for it precipitates and forms an inſoluble ſalt with lime water, and with the ſoluble ſalts of ſilver, lead, and mercury, and appears to be the *Malic* acid mixed with a little *Citric*, both of which are converted into vinegar by ſpontaneous decompoſition. The wines that contain the greateſt quantity of theſe acids yield the worſt brandy, nor is there any method yet known of ſeparating or neutralizing the acid without materially injuring the quality, or leſſening the quantity of the ardent ſpirit.

2. *Alcohol*. The exiſtence of this principle and mode of extraction by diſtillation has been fully deſcribed under the article *Brandy*. The quantity of alcohol varies prodigiouſly. The ſtrong, rich, full-bodied wines of the warmer vine countries will yield as much as a third of ardent ſpirit; whilſt the thin light wines will often give no more than about $\frac{1}{14}$th of the ſame ſtrength.

3. *Tartar*. This ſubſtance has alſo been fully deſcribed in its proper place. Tartar is not altogether a product of the fermentation of wine, ſince it is contained in muſt, though in ſmall quantity.

4. *Extract*. Muſt contains an abundance of extractive matter, which materially aſſiſts the fermentation, and is afterwards found, in part at leaſt, in the lees, but another portion may be obtained from the wine by evaporation. It is alſo extract that mixes with and colours the tartar. By age the quantity of extractive matter diminiſhes.

5. *Aroma*. All wines poſſeſs a peculiar and grateful ſmell, which would indicate a diſtinct aromatic principle, but it has never been exhibited in the form of eſſential oil, or condenſed in any ſmaller quantity by diſtillation or any other mode. To give wine all its aroma it ſhould be fermented very ſlowly.

6. *Colouring Matter*. The huſk of the red grape contains a good deal of colour, which is extracted when the entire fruit is preſſed, and becomes diſſolved in the wine when the fermentation is compleat. Many ſubſtances will ſeparate the colour. If lime-water is added to high-coloured wine a precipitate is formed of malat of lime that carries down with it all the colouring matter, which cannot again be ſeparated either by water or alcohol. But if wine alone is evaporated gently to dryneſs, and the reſidue treated with alcohol, the colouring matter diſſolves therein. We may add too, that the natural colour of wine is entirely and ſpeedily deſtroyed by the addition of hot well-burnt charcoal in pretty fine powder. The colour of red wine in the ſtate in which we receive it is not entirely that of the grape, but is given by other colouring ſubſtances, which however are quite innoxious.

WITHERITE. *Barolite*, Kirw. *Native carbonat of barytes*.

Its colour is yellowiſh-grey, paſſing into greyiſh-white and pale wax-yellow. It occurs in maſs, diſſeminated, and rarely cryſtallized. Its forms are 1. a flattened hexahedral priſm terminated by hexahedral pyramids.

2. The ſame, with the lateral edges of the priſm and pyramid truncated.

3. A pyramidal dodecahedron.

The cryſtals are in general very ſmall, either implanted in the maſſive varieties of this mine-

* An. Chim. Tom xxv, xxvi, and xxvii.

ral, or grouped in bundles: their surface is generally rough. The longitudinal fracture of Witherite is between radiated and lamellar, and has a shining lustre; the cross fracture is fine-grained uneven, and glimmering with a greasy lustre. Its fragments are wedge-shaped. The massive variety often presents scapiform and wedge-shaped distinct concretions. It is translucent, passing to semi-transparent. Its hardness is about equal to that of fluor: it is brittle and easily frangible. Sp. gr. 4.3.

Before the blow-pipe on charcoal it first crackles a little, and then melts into a whitish enamel. Strong nitric acid has little or no effect upon it, but when very diluted, this menstruum dissolves it readily with a copious effervescence.

When pure it consists of	78	Barytes
	22	Carbonic acid
	100	

A specimen from Anglezark afforded Klaproth

98.246	Carbonated barytes
1.703	Carbonated strontian
0.043	Alumine with a little iron
0.008	Carbonated copper
100.	

Witherite is an active poison to animals.

It was first discovered by Dr. Withering at Anglezark, in the north of Lancashire: it has since been found in the Schlangenberg in Siberia, and also near Neuberg in Upper Stiria.

It occurs at Anglezark in veins in slate, accompanied by heavy spar, galena, blende, and calamine.

WOAD. This valuable dyeing drug (the use of which however has been a good deal superseded by indigo) gives a full bodied and very fast blue to wool, but not very bright, so that it is always mixed with indigo at present. The mode of preparing the woad-vats is mentioned under the article *Dyeing*, p. 373.

The mode of cultivating and preparing the woad in Thuringia is thus given by Wedelius.[a] Woad requires a very rich deep soil well manured and tilled. The seed is put in the ground in February. In June the leaves turn yellowish, and the plant begins to flower, which is the time for gathering the first crop, which is done by mowing down the whole plant close to the ground. It is then rinced in water and spread out in the sun, and when dry enough it is ground in mills to a fine paste, which is further dried by ventilation. This paste is then made up into cakes, which are heaped upon each other in a covered room, whereby they soon ferment, heat, and exhale a most penetrating nauseous ammoniacal odour which spreads to a great distance: this fermentation is kept up for a sufficient time, occasionally watering the cakes when the heat is too great, till the whole falls into a coarse powder, in which state the woad is again made up into balls, and is ready for use.

The root of the plant throws out a fresh crop of young shoots which are fit to cut in about six weeks after the first harvest, and are managed in the same way, and sometimes, if the season continues dry and warm, a third crop may be got in the same year, but this is much inferior to the two first.

The fermentation of the woad plant is peculiarly violent, and attended with an uncommonly nauseous smell, and the production of a large quantity of ammonia. Much practical skill is required in the management of it, for if suffered to heat too much the whole is converted to a black effete mass, and the blue colour, for which the plant is cultivated, is totally destroyed. The fermentation is both moderated and prolonged by the great hardness of the cakes, which cannot easily be broken up till they crumble to pieces of themselves by their spontaneous action.

When woad is distilled *per se*, it gives out a considerable quantity of ammonia along with the other principles common to vegetable matter. Nitric acid has but little action on it, in which it differs remarkably from indigo. The colour however is totally destroyed. According to the imperfect experiments of Dijonval[b], sulphuric acid acts on woad with great vehemence, causing much tumefaction and disengagement of gas, and a solution is at last effected, which, diluted with water, is a faint undefinable green, without any thing of the fine blue which distinguishes the sulphat of indigo. When woad is diffused in water and kept for a time it speedily putrefies, and gives a more penetrating and fetid smell than most vegetable or even animal matter under similar circumstances.

WOLFRAM. See TUNGSTEN.

WOOD. *Bois*, F. *Holz*, G.

The wood of vegetables consists obviously of a dense congeries of fibres abundantly impregnated with a variety of the natural juices of the plant, such as mucilage, resin, colouring

[a] Ephem. Nat. Cur.

[b] Journ. Phys. Tom. xi.

extract, essential oil, sugar, &c. all of which may be obtained from one or other kind of wood, by applying those menstrua which dissolve these substances in their natural state. But after the action of these menstrua has been exhausted, after wood has been long boiled in water, alcohol, and weak acids, a substance remains, which is not in any degree acted on by these, which burns in the open air without melting, but with much flame and a penetrating acid vapour, and leaves at last only a small quantity of white earthy ash, from which a small portion of alkali may be extracted. This substance is considered as the pure woody fibre, and has some title to be considered as a distinct vegetable principle, as it has some properties peculiar to itself. The earth and alkali (or neutral salts, which, by combustion, furnish the alkali) must however be reckoned as foreign to the pure ligneous fibre, though they cannot be extracted without entire disorganization of the wood.

It is not easy to extract all the soluble parts of fresh wood, such as the resin and colouring matter, without first reducing it to very fine dust, for M. Sennebier[a] found that even the thinnest shaving of entire wood long resisted the action of common menstrua. But after bruised wood has been long boiled alternately in water and alcohol, and again thoroughly dried, it then loses so much of its cohesion that it may be reduced to very fine powder, from which a subsequent application of the same liquors will compleat the extraction of every thing soluble.

The residue, which is as pure woody fibre as can be obtained, when heated strongly in a retort, without addition, yields a considerable quantity of a red pungent acid liquor, which has long been considered as a peculiar acid, and has been called the *pyroligneous*, but later experiments render it probable that it is little else than the *acetous* holding some empyreumatic oil in solution. Its general properties are described under the article *Acetous Acid (Empyreumatic)*. But it is to be observed that it is commonly procured by the simple distillation of wood unprepared by any previous process, and of course may be mixed with a portion of all the other ingredients of wood which are volatile by fire and again condensible in a liquid form; nor do we know of any experiments made in a sufficiently large way, on the acid yielded by wood on which the action of water and alcohol has previously been exhausted.

The pure ligneous fibre is decomposed by being heated with strong nitric acid, and yields a very considerable quantity of oxalic and malic acid. The caustic alkalies also soften, and finally dissolve it.

The surface of wood is readily stained by a variety of substances, and if these are allowed to remain in contact with it they sink into the substance of the wood which often produces a very agreeable effect in cabinet work, and sometimes gives to ordinary wood a very good resemblance of the more expensive coloured woods of foreign countries.

The following experiments to this purpose have been made by Beckman.[b] Some maple wood was first sawed into thin slips about $\frac{1}{12}$ of an inch in thickness. One of these was immersed in a solution of dragon's blood in oil of turpentine. After a considerable time the wood had absorbed so much of the resin as to sink in the liquor, and it was then of a fine mahogany colour, shewing the veins of the wood by a lighter shade of red. Another slip of wood was dyed in the same manner in a solution of gamboge in oil of turpentine, which gave a fine yellow, and by a mixture of gamboge and dragon's blood in different proportions, a number of beautiful tints may be produced. Beech-wood was found to take the colour sooner, but it was less brilliant. A solution of these resins in alcohol also answered very well. With these kinds of substances, however, it is necessary in order to produce a good colour, either to boil the wood in the liquor, or at least to continue the digestion for a considerable time, so that they can only be employed to great advantage with small pieces, such as are used for the finer kinds of inlaying or veneering. But many saline and metallic solutions produce a more speedy effect in changing the colour of wood, which may be applied to a surface of any extent.

All the white woods are rendered much whiter by being soaked in a solution of alum. This is probably owing to a decomposition of the salt, and a deposition of its earth within the pores of the wood in very fine division.

A deep black is given to wood in various ways. Oak and other woods that abound in gallic acid receive a black from the solutions of iron, but these woods are comparatively rare.

If concentrated sulphuric acid is smeared over the surface of wood it blackens it very speedily, and this colour spreads deep within the wood in a few hours, its surface being at the

[a] Journ. Phys. Tom. xxxviii.

[b] Nov. Com. Soc. Goting. Tom. vii.

ſame time covered with a tenacious froth. When this is thoroughly waſhed off, and the wood dried, the ſurface is of a deep charcoal black, and hard enough to take a good poliſh; but it is not eaſy to get rid of every particle of the acid. A much finer and better black is given by firſt ſoaking the wood in any ſolution of lead, and afterwards for a day or two in a ſolution of arſenical liver of ſulphur, made by boiling in water a mixture of two parts of quicklime and one of orpiment. Probably the ſimple ſulphuret of lime would anſwer as well. All the other metallic ſolutions that naturally blacken with the ſulphurets will anſwer the ſame purpoſe, ſuch as thoſe of ſilver, biſmuth, and iron, but lead ſucceeds the beſt.

With the woods that contain no gallic acid a yellow-brown dye, varying to brown-red, is given by ſmearing them over a few times with a ſolution of iron in dilute nitric acid.[c] This dye is very permanent, and does not change by the action of light or air.

A greeniſh hue may be given by the ſolutions of copper, but it is difficult to make wood take it equally, or to give any depth of colour by this metallic ſolution.

Different hues may be given by ſtrong decoctions of the colouring woods and other dyes mixed with alum, which need not be here enumerated.

In all the above proceſſes, and particularly where any ſaline or metallic ſolution is employed, the natural gloſs of the wood is much impaired, which requires that it ſhould be finiſhed with linſeed, or amber, or any ſimilar varniſh, which has the effect both of rendering the dye more permanent, and of much increaſing its beauty.

WOOD, *petrefied.*

Wood in ordinary circumſtances, whether upon the ſurface of the earth or buried under it, is by degrees, by the concurrent action of air and water decompoſed; its texture is broken down, the connexion between the ſeveral vegetable principles of which it conſiſts is diſſolved, its ingredients enter into new combinations, and no veſtige remains either of its organization or chemical properties. Sometimes however it happens that the external figure and internal arrangement are preſerved while the chemical properties have undergone very notable alteration, in conſequence of which the natural decay is prodigiouſly retarded, and ſometimes even wholly ſuſpended. Wood that has undergone this change is ſaid to be petrefied, or mineralized.

There are three ſubſtances by which this change is brought about, namely pyrites, oxyd of iron, and ſiliceous earth in the form of agate or hornſtone. Theſe conſtitute ſo many ſpecies of petrefied wood.

The *pyritous foſſil wood* occurs principally in the independent coal formation; it is compoſed entirely of common pyrites, often in a ſtate of ſemi-decompoſition: it appears to contain no ligneous particles, but retains with conſiderable exactneſs the external figure, and in ſome degree the internal organization of wood. The reaſon why this ſpecies preſents a leſs ſtriking reſemblance to wood than the others do, is probably the ſtrong cryſtalline polarity which pyrites poſſeſſes; in ſplitting longitudinally a piece of pyritized wood it not unfrequently happens that the fibres repreſenting the concentric layers of wood are compoſed of minute cubes laterally aggregated to each other.

The *ferruginous foſſil wood* is found in hematite, and eſpecially in argillaceous iron ore. Externally it preſents the appearance of trunks and branches, and its internal texture has a cloſe reſemblance to that of wood. In its chemical compoſition it does not appear to differ materially from common argillaceous iron ore.

But *agatized wood* is that which has been the moſt examined. It has been made a diſtinct mineral ſpecies by Werner, who has given it the name of HOLZSTEIN or Woodſtone, of which the following are the characters.

Its colour is aſh-grey, paſſing into greyiſh-black, yellowiſh, browniſh, and blood-red: the colours run into each other forming clouds and ſtripes in a longitudinal direction. It occurs in the form of trunks, branches and roots, and preſents in the utmoſt perfection the internal organization of wood, not only the longitudinal fibres and concentric layers being viſible, but even the knots and medullary proceſſes. Its internal luſtre is various, being between gliſtening and dull. Its croſs fracture is imperfectly conchoidal, its longitudinal fracture is ſplintery and fibrous. It is moderately tranſlucent; is harder than glaſs, and gives fire with ſteel, but is eaſily frangible.

It occurs in ſand and ſandſtone in various countries, eſpecially in the hill St. Symphorien, near Etampes in France, in Saxony, Bohemia, and Hungary; near Loch Neagh in Ireland, in the beds of ſandſtone that lie above the fuller's

[c] Repertory, Vol. xiv.

earth near Woburn in Bedfordſhire, and alſo in the ſandy deſarts to the weſt of Egypt.

It not unfrequently happens that agatized wood before the petrefying proceſs has begun, has been corroded by worms, in which caſe not only the perforation is filled with ſiliceous matter, but even the ſubſtance of the worm itſelf has been compleatly agatized.

Agatized wood diſcovers ſlight traces of its origin by affording a few drops of a watery empyreumatic liquor by diſtillation: it conſiſts however for the moſt part of ſilex.

The origin of petrefied wood is generally attributed to the gradual infiltration of the petrefying ſubſtance, but to this theory, however ſimple and ingenious, there are many important objections.

WOOD-STONE. See the preceding article.

WOOD-OPAL. See Opal.

WOOL. *Laine*, Fr. *Wolle*, G.

This ſubſtance, the material of ſuch important manufactures, poſſeſſes ſome curious chemical properties, none of which however are much illuſtrated by the various operations performed on it in manufacture, almoſt all (that of dyeing excepted) being purely mechanical proceſſes.

Some of the ſimple chemical properties of wool have been examined by M. Achard,[a] and compared with the correſponding properties of the hair of different animals. The copious generation of *oxalic acid* by treatment of wool with nitric acid, has been particularly deſcribed and explained by M. Berthollet in his beautiful reſearches on animal matter; and the great ſolvent power of the cauſtic fixed alkalies, has been happily applied to ſome uſe by M. Chaptal as a ſaponaceous compound.[b]

Wool in the ſtate in which it is taken from the ſheep is always mixed with a great deal of dirt and foulneſs of different kinds, and in particular is ſtrongly imbued with a natural ſtrong-ſmelling greaſe. Theſe impurities are got rid of by waſhing, fulling, and combing, by which the wool is rendered remarkably white, ſoft, clean, light, and ſpringy under the hand. When boiled in water for ſeveral hours in a common veſſel, wool is not in any way altered in weight or texture, nor does the water acquire any ſenſible impregnation.

A little action is ſhewn between water and wool by boiling for an hour in a high heat, with a Papin's digeſter,[c] the water acquires a ſmell like that of raw wool, and the wool is ſomewhat whitened, but its weight is not ſenſibly changed, nor its texture materially altered. In this reſpect it differs ſomewhat from hair, the texture of which is much ſoftened whilſt it is wet, by boiling in a digeſter, but when dry it becomes quite criſp and brittle.

Sulphuric acid added cold to wool produces neither heat nor any vapour, but after a few hours the acid blackens, and the wool loſes its texture, becomes ſoft and gelatinous, and finally diſſolves, forming a black thick acid liquor.

The action of the nitric acid on wool is undoubtedly the moſt curious. When cold, this acid only diſengages a large quantity of azotic gas, but when warmed, much nitrous gas is given out, and at leaſt two new acids are formed, viz. the *malic* and the *oxalic*, the latter is in greater abundance than even from ſugar and nitrous acid, or any other hydro-carbonous baſis. A ſmall ſcum of a peculiar oil always ariſes during the action of nitrous acid on theſe animal ſubſtances. See the article Oxalic Acid.

Muriatic acid when boiled on wool ſimply diſſolves it. The ſolution is dark brown, and is not changed by the addition of water.

The action of the oxymuriatic acid has not been further examined than to diſcover that it does not whiten wool as it does cotton, but on the contrary, turns it to a pretty deep yellow; which may occaſionally furniſh an uſeful method of diſtinguiſhing the fibre of wool from that of cotton in any kind of cloth where they may be mixed.

No effect is produced by boiling wool in the oils, fixed or eſſential, or in alcohol.

The carbonated alkalies have little action on wool, but the cauſtic fixed alkalies when digeſted with it ſpeedily weaken its fibre, reduce it to a ſoft gelatinous pulp, and finally make a perfect ſolution. The alkali at the ſame time loſes its alkaline properties as it does in common ſoap. This ſaponaceous ſolution of wool is made for experiment in a few minutes by boiling bits of wool or flannel in a cauſtic alkaline ſolution, and it has been recommended by Chaptal to be employed inſtead of common ſoap in cleanſing cotton and other goods in manufactures, as by this means a number of refuſe bits and clippings of wool and woollen cloth which are now thrown away may be put to ſome uſe. This ſoapy ſolution does not lather well when agitated with water, nevertheleſs it acts very powerfully in cleaning cloth. It has a ſtrong and ſomewhat offenſive ſmell,

[a] Mem. de l'Acad. de Berlin, for 1782. [b] An. Chim. Tom. xxi. [c] Achard.

which is left at first in the cloth, but goes off by short exposure to the air.

M. Achard distilled *per se* in a retort one ounce of wool, with a heat gradually increased to ignition. There was left in the retort 2¼ drams of a coaly residue; the neck of the retort was lined with a black shining soot; beyond which was a saline sublimate; and in the receiver was about 2 drams of an empyreumatic oil, together with some neutral ammoniacal salt, the nature of which was not ascertained.

WOOL *Philosophical*. See Zinc.

WORMWOOD, *Salt of*.

The purer kinds of salt of tartar or carbonat of potash were often termed salt of wormwood, particularly in medicine, the ashes of this plant yielding an abundance of this alkali. See *Carbonat of Potash*.

WORM-TUB. A part of the common distilling apparatus. (*See the Appendix.*)

WOULFE's APPARATUS. (*See the Appendix.*)

WURFELSPATH. See Anhydrous Selenite, p. 547. Vol. I.

Y

YEAST. See Fermentation.

YELLOW (*Naples*).

The Naples Yellow (*Giallolino*) is a fine pigment long prepared at Naples, which has the appearance of an earth, is very friable, heavy, porous, not alterable by exposure to air, and of a pale orange-yellow colour. When heated it exhales no sensible vapour, melts when red-hot, but undergoes no other change except that the colour becomes deeper. Boiling water and acids extract a portion from it, but do not dissolve it entirely.

This pigment (the preparation of which is kept secret) has been examined by several chemists, but no accurate analysis has been made of it. Fougeroux shewed that it was a metallic oxyd by reducing it with a proper flux, and easily obtained a regulus from it, which consisted of lead and antimony.[a] Beckman and Couret have confirmed this composition. A process which produces a similar pigment is thus given by Couret.[b] Mix together 12 oz. of ceruse, 3 oz. of diaphoretic antimony, of alum and sal-ammoniac each one ounce, heat them for a considerable heat below redness, and afterwards in a red heat for three hours longer, after which the mass will have acquired a beautiful yellow colour.

The Giallolino is little employed in this country, its use being supplied by *Turner's Patent Yellow*, prepared from Lead in the manner described under that article.

YELLOW EARTH. *Gelberde*, Wern. *Terre jaune*, Broch.

Its colour is ochre-yellow; it occurs in mass; it is dull or at most feebly glimmering. Its fracture in the great is slaty, but in small is fine-grained earthy, passing into imperfectly conchoidal. It is very soft, almost friable; it acquires a polish by friction; stains the fingers, and is somewhat unctuous to the touch, it adheres slightly to the tongue, and is of little specific gravity.

It is employed in the arts as a pigment.

It forms beds in clay, and ironstone, at Wehrau, in Upper Saxony.

YTTRIA. See Gadolinite.

Z

ZAFFRE. See Cobalt.

ZEICHENSCHIEFER. See Thonschiefer.

ZEOLITE. *Zeolith*, Wern.

Of this mineral there are the three following subspecies.

1. *Subsp.* Radiated Z. *Strahliger*, Z. Wern. *Mesotype*, Hauy.

Its colour is yellowish-white, greyish, reddish and snow-white. It occurs massive, globular, and crystallized. Its primitive form is a rectangular, tetrahedral prism: sometimes the prism is terminated by tetrahedral pyramids, the bases of which correspond with the faces of the prism: sometimes the prism is compressed, and terminated by tetrahedral pyramids set on the lateral edges of the prism; the summits of the terminal pyramids are also often truncated. The crystals are middle-sized and small, and often laterally aggregated, so that their summits alone are distinguishable: the lateral planes are smooth and shining. Internally it is glistening, with a pearly lustre. Its fracture is divergingly

[a] Mem de l'Acad. for 1766. [b] J. Phys. Tom. xxxvi.

radiated, approaching on one hand to foliated, and on the other to fibrous. It presents longish granular distinct concretions. It is translucent, passing into transparent, and possesses a double refraction. Its hardness is somewhat superior to that of calcareous spar; it is brittle and easily frangible. Sp. gr. 2.03 = 2.08.

Before the blow-pipe it intumesces and melts like borax. It is soluble in the mineral acids, and forms with them a gelatinous mass. Its component parts, according to Vauquelin, are

50.24	Silex
29.3	Alumine
9.46	Lime
10.	Water
99.	

It passes into the two following varieties.

Var. 1. Fibrous Z. *Fasriger Z.* Wern.

Its colours are nearly the same as the preceding, except that it sometimes occurs wax-yellow and greenish-white. It occurs in mass, reniform, and in capillary crystals. Its fracture is divergingly fibrous, passing into splintery. In other respects it agrees with the preceding.

Var. 2. Mealy Z. *Mehlzeolith*, Wern.

Its colours are yellowish and reddish-white passing into flesh-red. It occurs massive, coralloidal, and incrusting other zeolites. It is dull; its fracture is coarse earthy, approaching to finely fibrous. It is opake; very soft, almost friable; very light; and when rubbed with the nail it gives a grating feel and noise like burnt brick.

2. *Subsp.* Lamellar Z. *Blattriger Z.* Wern. *Stilbite* Hauy.

Its colour is yellowish and greyish-white, rarely reddish-white. It occurs massive, globular and crystallized. Its primitive form is a rhomboidal prism: the other varieties that it presents are, a short hexahedral prism, the opposite faces alone of which are equal; and a table of six equal sides. The crystals are small and middle-sized, and their surface is always smooth and shining. Internally its lustre is shining and pearly. Its fracture is lamellar, generally somewhat curved, and is divisible only in one direction. It presents granular and sometimes curved lamellar distinct concretions. When in mass it is translucent, and when crystallized is generally transparent. In its other characters it resembles the preceding subspecies.

It is composed, according to Vauquelin, of

52.	Silex
17.5	Alumine
9.	Lime
18.5	Water
97.	

3. *Subsp.* Cubic Z. *Wurfel Z.* Wern. *Analcime & Chabasie* Hauy.

Its colour is greyish and yellowish-white, and yellowish-brown. It occurs in mass and crystallized. The primitive form of its crystals is a hexahedron approaching very near to a cube; sometimes each solid angle of the cube is replaced by an obtuse trihedral pyramid set upon the faces of the cube: sometimes these secondary faces are so large as to obliterate those of the primitive crystal, whence there results a solid with 24 trapezoidal faces. The crystals are small and middle-sized, and are brightly shining externally with a lustre between vitreous and pearly. The internal lustre is somewhat inferior to the external. Its fracture is imperfectly lamellar in three directions, passing sometimes to uneven. Its fragments have a strong tendency to the cubical form. It presents granular distinct concretions; is translucent, passing to transparent; is somewhat harder than glass. Sp. gr. 2.7.

It intumesces before the blow-pipe, but does not gelatinize with acids.

Zeolite occurs principally in the most recent floetz trap-formation, especially in amygdaloid and cellular basalt; in these rocks it sometimes only lines, but often entirely fills up the cavities which they contain. It also occurs, though rarely, in primitive greenstone, and in veins accompanied by galena.

All the above subspecies occur in Scotland, but the largest and most beautiful specimens come from Iceland and the Ferroe Islands: they are also met with at Adelfors in Sweden, in various parts or Germany, and very abundantly in the South Sea Islands.

ZINC. *Zink*, Germ. *Zinc*, Fr. *Spelter*, *Tutenag*, of the Chinese.

Zinc is a bluish-grey semi-ductile metal, fusible at less than a red heat, and combustible at the lowest point of ignition, an extremely brilliant bluish-white flame being given out, and the metal being converted into a white flocculent oxyd.

§. 1. *Ores of Zinc.*

Sp. 1. Common Calamine, Native carbonat of Zinc.

Of this mineral there are the three following subspecies.

1 *Subsp.* Cryſtallized C.

Its colour is greyiſh-white and yellowiſh-grey. It occurs in rhomboids approaching very nearly to the cube, and in longiſh quadrilateral tables: the cryſtals are ſmall and very ſmall; both externally and internally they are uſually ſhining with a luſtre between reſinous and vitreous. Its fracture is ſmall and imperfectly foliated. It is tranſparent, paſſing into tranſlucent; it yields eaſily to the knife but not to the nail. Sp. gr. 4.33.

By ignition in a covered crucible it loſes about 34 *per cent.* It diſſolves totally and with efferveſcence in the mineral acids, and the ſolution does not gelatinize.

It is compoſed, according to an analyſis by Smithſon,[a] of

65.2	Oxyd of zinc,
34.8	Carbonic acid.
100.	

It occurs in veins in ſecondary limeſtone, accompanied by the other ores of this metal, by galena, calcareous ſpar, quartz, &c. It is found in Derbyſhire.

2 *Subsp.* Compact C.

Its colours are greyiſh, greeniſh and yellowiſh white, ochre yellow and yellowiſh brown, the two latter colours however indicate a contamination of iron. It occurs maſſive, cellular, botryoidal, mamillated, reniform and ſtalactitic. Its internal luſtre is gliſtening, between vitreous and reſinous. Its fracture is imperfectly fibrous paſſing to ſplintery and granular uneven. It preſents granular and curved-lamellar diſtinct concretions: the lighter coloured are tranſlucent at the edges. In hardneſs, ſpecific gravity, and chemical characters it differs but little from the preceding ſubſpecies.

It has been analyſed by Smithſon and Bergman[b] with the following reſult.

Sm.		Berg.	
64.8	—	64.	Oxyd of zinc,
35.2	—	28.	Carbonic acid,
0.	—	6.	Water,
0.	—	1.	Oxyd of iron.
100.		101.	

Concerning Bergman's analyſis it may be remarked, that the oxyd of iron is merely accidental, and that the exiſtence of the water is rather inferred than proved, ſo that probably the amount of carbonic acid is ſtated too low.

It occurs in the ſame geological ſituations as the preceding, and is very abundant in Cumberland, Derbyſhire, Flintſhire, and Somerſetſhire in England, and in a multitude of other places.

3 *Subsp.* Earthy C.

Its colour is greyiſh or yellowiſh white. It occurs in maſs, and encruſting the ſurface of other minerals. It is dull; its fracture is very fine grained earthy. It may be ſcraped by the nail; is opake, and adheres to the tongue. Sp. gr. 3.58.

It conſiſts, according to Smithſon, of

71.4	Oxyd of zinc,
13.5	Carbonic acid,
15.1	Water.
100.	

In its other properties it agrees with the preceding ſubſpecies.

It is found in Derbyſhire, in Bleyberg in Carinthia, and elſewhere.

Sp. 2. Electric Calamine.

Its colour is greyiſh, bluiſh or yellowiſh white: it occurs in maſs or cryſtallized. The form of its cryſtals is a compreſſed hexahedral priſm, terminated by low, bevilled, and truncated hexahedral pyramids. The cryſtals are ſmall and very ſmall, either ſolitary or grouped in divergent rays, like zeolite. The luſtre of the cryſtals is ſhining, vitreous; their fracture is imperfectly foliated; that of the maſſive variety is generally diverging fibrous. It varies from tranſparent to opake according as it is cryſtallized or not. It may be ſcratched by a knife, but is conſiderably harder than common calamine. Sp. gr. 3.43. When gently heated it becomes ſtrongly electrical, nor is this property deſtroyed even by a red heat. By ignition its loſs does not exceed 12 per cent, and the cryſtals though they become opake and decrepitate a little, do not fall to powder. It is ſoluble in the mineral acids without efferveſcence, conſiderable heat is extricated, and the ſolution gelatinizes on cooling.

The maſſive variety from Hungary was analyſed by Bergman, and another ſpecimen from Wanlock-Head by Klaproth; that in radiated cryſtals, like zeolite, from Fribourg, by Pelletier;[c] and that in ſolitary cryſtals, from Regbania in Hungary, by Smithſon, with the following reſults.

[a] Phil. Tranſ. for 1803, p. 17. [b] Opuſcula, ii. p. 324. [c] Memoires, i. p. 49.

Berg.		Klapr.		Pellet.		Smith.	
84.	—	66.	—	36.	—	68.3	Oxyd of zinc,
12.	—	33.	—	52.	—	25.	Silex,
0.	—	0.	—	12.	—	4.4	Water,
3.	—	0.	—	0.	—	0.	Oxyd of iron,
1.	—	0.	—	0.	—	0.	Alumine.
100.		99.		100.		97.7	

It occurs in fecondary limeftone accompanied by quartz, calcareous fpar, common calamine, &c.

Befides the localities above mentioned it alfo occurs in Derbyfhire.

Sp. 3. Blende. *Black Jack*, of the Englifh miners. *Pfeudogalena.*

Of this there are the two following fubfpecies.

1 *Subfp.* Foliated B.

Its colour is wax and fulphur yellow, brownifh and olive green, reddifh or yellowifh, or blackifh brown paffing into perfect black, alfo hyacinth red, brownifh and blood red. It occurs in mafs, diffeminated or cryftallized. Its primitive form is the rhomboidal dodecahedron; the others that it prefents are.

1. The regular octohedron.
2. The pyramidal tetrahedron.
3. Var 1, with all the edges truncated.
4. Ditto, with both the edges and folid angles truncated.
5. A folid with twelve trapezoidal faces and twelve ifofceles triangular faces.
6. The preceding variety with four of the folid angles replaced by an equal number of equilateral triangles.

The cryftals are generally fmall, and fo impacted together that it is not eafy to determine their forms: their furface is fmooth and fplendent. The external and internal luftre of this mineral is brightly fhining between refinous and adamantine, in the darker coloured varieties paffing to femi-metallic. The fracture is ftrait foliated in fix directions, but when made acrofs the laminæ is imperfectly conchoidal. Its fragments are angular and pretty fharp-edged. It prefents granular diftinct concretions. The lighter coloured cryftals are tranfparent and tranflucent, the darker coloured ones and the maffive varieties are tranflucent at the edges and opake. Its hardnefs is about equal to that of fluor fpar; it is brittle and eafily frangible. Sp. gr. 4.04 = 4.16.

2 *Subfp.* Fibrous B.

Its colour is iron grey mixed with yellowifh particles; it occurs in cellular, reniform, and ftalactitical maffes: externally it is dull: internally it is gliftening or glimmering; its fracture in one direction is finely and divergingly fibrous; the crofs fracture is conchoidal; it it compofed of curved lamellar diftinct concretions. It is opake, moderately hard and brittle. Sp. gr. 3.63.

It has hitherto been found only at Geroldfeck in the Brifgau, in a vein accompanied by galena and heavy fpar.

The yellow foliated blende is phofphorefcent by friction, even under water. Several of the blendes give out an hepatic odour by friction, and ftill more of them by digeftion in muriatic acid.

They have been fubjected to various analyfes, but hitherto not with fufficient precifion. The following is a table of the different refults.

	Zinc	Sulphur	Iron	Lead	Copper	Arfenic	Fluor.ac	Water	Silex	Alumine
Yellow B. by Bergman	64.	20.	5.	0.	0.	0.	4.	6.	1.	0. = 100.
Brown B. by Bergman	44.	17.	5.	0.	0.	0.	0.	5.	24.	5. = 100.
by Dr. Thomfon	58.8	23.5	8.4	0.	0.	0.	0.	0.	7.	0. = 97.7
Black B. by Bergman	45.	29.	9.	6.	0.	1.	0.	6.	4.	0. = 100.
by Lampadius	53.	26.	12.	0.	0.	5.	0.	4.	0.	0. = 100.
Black B. with metallic luftre by Bergman	52.	26.	8.	0.	4.	0.	0.	4.	6.	0. = 100.
Fibrous B. by Hacht	62.	21.	3.	5.	0.	1.	0.	4.	0.	2. = 98.

Blende occurs in transition, primitive, and stratified mountains, but principally in the former: it is found in veins almost always accompanied by galena, calcareous spar and quartz, also by iron pyrites, fahlerz, native silver, grey antimony, spathose iron, copper pyrites, heavy spar, &c. The Hungarian and Transilvanian blendes are often auriferous.

Blende abounds in Britain, and in most of the other mining districts of Europe.

§. 2. *Assay and Analysis.*

Common Calamine, besides carbonat of zinc and water, may also contain the carbonats of iron, lead and lime. Its analysis may be thus conducted. (*a*) Dissolve the pulverized ore in dilute nitric acid and estimate the *carbonic acid* from the loss of weight during the solution. Then carefully neutralize the solution by a little caustic soda and evaporate it gently, adding from time to time a few drops of sulphat of soda as long as any precipitation takes place. (*b*) Having thus cautiously brought it nearly to dryness, digest it in highly rectified alcohol, and afterwards in a little cold water which will take up every thing but the sulphats of lead and lime. (*c*) These may then be separated by digestion in very dilute sulphuric acid, which will take up the sulphat of lime, leaving the sulphat of *Lead* pure. (*d*) Neutralize the muriatic solution by soda, and evaporate nearly to dryness; then add to the residue alcohol, which will throw down the sulphat of *Lime* with a little sulphat of soda, this latter may then be washed away by a little cold water. (*e*) The alcoholic solution *b* after evaporation to dryness may be digested in caustic ammonia, which will take up the oxyd of zinc and leave behind the oxyd of *Iron*. (*f*) The alkaline solution after being slightly supersaturated with muriatic acid, is to be decomposed by a perfectly carbonated alkali, by which the zinc is procured in the state of carbonat, and this, after edulcoration, being dissolved by sulphuric acid and the solution ignited in a platina crucible affords dry sulphat of *Zinc*, containing 50 per cent. of oxyd of zinc. (*g*) Thus all the component parts are ascertained except the water; to determine the proportion of this take a fresh parcel of the ore, weigh it, and then ignite it for half an hour, note the loss of weight, and transfer the residue into muriatic acid; if while it dissolves in this fluid it gives out any gas let the loss of weight be noted; then add together the losses by ignition and solution, deduct from the sum the known weight of the carbonic acid and the residue is *water*.

To analyse the *electric calamine* dissolve the pulverized ore in dilute nitric acid, evaporate the solution very slowly, almost to dryness, then digest it in a large quantity of water and the silex will remain undissolved. If the silex retains the least ochery tinge digest it in dilute muriatic acid, by which the adhering oxyd of iron will be taken up. Then decompose the muriatic solution by a carbonated alkali, and transfer the oxyd thus obtained to the nitric solution from which the silex has been separated. The rest of the analysis is the same as already mentioned for common calamine.

The analysis of *Blende* is considerably more complicated. The substances that have been obtained from it by decomposition are zinc, iron, lead, copper, arsenic, sulphur, silex, alumine and water; nor is it by any means improbable that the whole of them should coexist in the same specimen, we shall therefore proceed to mention what appears to us as the best method of separating these substances from each other.

a For the *Water*; let 200 grs. duly pulverized be put into a small coated glass retort and gently ignited for a quarter of an hour; the fluid in the receiver will be water with scarcely any perceptible admixture of sulphurous acid.

b Now take another portion of the ore and digest it in repeated portions of dilute nitric acid till every thing soluble is taken up; wash the residue, weigh it and ignite it; the *Sulphur* will burn off, and its amount may be estimated by the loss of weight.

c The residue, after the ignition of the sulphur, is to be digested in a little nitro-muriatic acid till the insoluble portion becomes quite white, and is then pure *Silex*.

d To the nitric solution (*b*) add a few drops of sulphated soda and evaporate it gently, continuing to drop in from time to time a little sulphated soda as long as any precipitation takes place; when the whole is brought nearly to dryness digest it in very dilute muriatic acid, which will take up every thing but the sulphat of *Lead*.

e Add together the nitro-muriatic solutions, (*c*, *d*) and decompose the whole by carbonat of soda, then digest the precipitate thus obtained in caustic ammonia, by which the zinc and copper will be taken up.

f Saturate the preceding ammoniacal solution with muriatic acid, and then boil it, adding caustic soda as long as any precipitate falls down; this precipitate is brown oxyd of *Copper*.

g The soda solution, now containing only oxyd of zinc, is to be saturated with muriatic

acid, decomposed by carbonat of soda, and the precipitate thus procured, after ignition, is oxyd of *Zinc*.

h The residue insoluble in ammonia (*e*) is to be abstracted repeatedly with nitric acid, and then digested in caustic soda: what remains insoluble is oxyd of *Iron*, with a slight contamination of arsenic.

i The preceding soda solution is to be saturated with nitric acid, and nitrat of lead is to be added till it ceases to produce a precipitate. This precipitate is *arseniat* of lead.

k To the remaining fluid is first to be added sulphat of soda, in order to get rid of any nitrat of lead that it would probably contain, and the filtered liquor being decomposed by carbonated ammonia a precipitate will fall down, which, when well washed and ignited, is pure *alumine*.

A considerable difficulty however still remains in estimating properly the relative proportions of Blende, even after the analysis has been performed in the most careful manner. This arises from the uncertainty of the state in which the zinc and sulphur (which are the principal ingredients) exist in this ore. According to some chemists, pure blende, exclusive of all casual admixtures, is a true sulphuret of zinc, the latter being in the metallic state. The reasons adduced in favour of this opinion are, First, that this is conformable to the composition of the other native metallic sulphurets, such as the different species of pyrites, and the sulphurets of lead, antimony, silver, &c. Secondly, that if blende be digested in muriatic acid sulphuretted hydrogen will be given out (as was first observed by Bergman) which gas can only proceed from the decomposition of water by the metallic zinc, and the union of its hydrogen with part of the sulphur, while in the act of being separated from the zinc by the powerful affinity of the acid for this last.

On the other hand, however, it may be remarked that metallic zinc and sulphur cannot be made to combine together by art, but that oxyd of zinc and sulphur unite by fusion, producing a yellowish compound not unlike blende. The transparency of this mineral is also a character in which it differs from the other proper metallic sulphurets. It is true that sulphuretted hydrogen is given out during its solution in muriatic acid, but this would also happen if the sulphuretted hydrogen pre-existed in the ore. It is the opinion of Vauquelin that blende is a sulphuretted oxyd, which often contains besides sulphuretted hydrogen, and this seems to be confirmed by the observation of Bergman[d] that *concentrated* sulphuric acid separates sulphuretted hydrogen from blende; which cannot happen with a proper metallic sulphuret. The deduction however from this fact is somewhat equivocal, for the proportion of sulphuretted hydrogen by concentrated sulphuric acid is greatly inferior to that produced by muriatic acid, and when it is considered that all blende affords by distillation a portion of water, is it not very possible that the hydrogen may be furnished by the decomposition of this last? But the production of sulphuretted hydrogen from it, by the agency of acids, by no means proves that the zinc must necessarily be in one of the forms above-mentioned; common liver or glass of antimony, which is decidedly a sulphuretted sub-oxyd, affords sulphuretted hydrogen when digested with acids, and it appears highly probable, on taking into consideration all the properties of blende, that this also is a sulphuretted sub-oxyd.

The ores of zinc cannot be assayed in the common method on account of the great volatility of this metal, they are therefore treated in one of the two following ways.

1. The ore, being first bruised, is to be very carefully separated from any intermixed particles of galena and other impurities, and is then to be roasted, care being taken, especially in an assay of blende, that the whole of the sulphur is driven off. The roasted ore is now reduced to fine powder, together with half its weight of charcoal, and the mixture is put into an earthen retort, to the beak of which a tube or adopter is fixed dipping in water. After the retort with its contents has been exposed for about three quarters of an hour to a high heat in a wind furnace, it is to be cooled gradually, and on breaking the vessel the zinc will be found concreted in metallic drops in its neck.

2. The ore, after being prepared and mixed with charcoal, as above mentioned, is to be stratified in a crucible with its own weight of copper clippings; a perforated cover being luted on, the crucible is to be kept at a cherry red or low white heat for the best part of an hour, being then allowed to cool, its contents are taken out and washed, by which the globules of brass are readily separated from the lighter impurities. The excess of weight which the brass has over the copper employed, indicates the quantity of zinc absorbed from the ore.

§. 3. *Reduction of Ores.*

The ore, whether calamine or blende, after

[d] Bergm. Opusc. ii. p. 338.

being raifed from the mine, is firft dreffed, that is, it is broken to fmall pieces, and the galena, pyrites, and other impurities are feparated as accurately as poffible by hand; it is next calcined at a moderately red heat in a reverberatory furnace, by which the calamine is deprived of its carbonic acid, and the blende of the moft part of its fulphur. It is then wafhed, by which the lighter earthy parts are feparated from the metallic oxyd, which latter, being dried, is intimately mixed with about $\frac{1}{8}$ of its weight of charcoal by grinding the ingredients together in a mill, and is now ready to be fmelted. The furnace in which the reduction is performed is a circular one not unlike that of a glafs-houfe, in it are fixed fix large earthen pots, about four feet high, and nearly of the fame fhape as oil jars: into the bottom of each pot is inferted an iron tube that paffes through the arched floor of the furnace, and dips in a veffel of water placed beneath, while the other end of the tube rifes within the crucible to within a few inches of its top. Thefe crucibles are filled up to the level of the tube with the mixture of roafted ore and charcoal, the cover of each is very accurately luted on, and the furnace is charged with fuel, by which an intenfe heat is kept up for feveral hours. The zinc, as it is reduced, afcends to the top of the pot in the form of vapour, and there being prevented from efcaping by the clofely luted cover it defcends through the central iron tube, whence it paffes into the water, and is there condenfed in fmall drops. Thefe globules are afterwards melted and caft into ingots, in which ftate they are brought to market.

Common zinc generally contains a little lead, copper, arfenic, iron, manganefe, and probably plumbago, which often confiderably impair the quality of the alloys into which it enters. In order to get rid, in part at leaft, of thefe impurities, the common practice is to melt the zinc in a crucible, and then to ftir into it, by means of a ftick or earthen rod, a mixture of fulphur and fat: the latter of thefe preferves the zinc from oxydation, while the former, uniting with all the metals prefent, except the zinc, converts them into fulphurets, which rifing to the top form a fcoria that may be fkimmed off: this is to be repeated as long as any fcoria makes its appearance. M. Prouft objects to this method as completely ineffectual and propofes another, which is fimply rediftilling the zinc in an earthen retort; after the metal has paffed over there remains behind a mixed mafs of oxyds and other impurities. But it is not very obvious how either the arfenic or lead can be thus got rid of, nor does it by any means appear that the old method is fo very nugatory. It would probably be an improvement firft to heat the zinc nearly to melting, in which ftate it is very eafily pulverizable, and having thus reduced it to fine powder, to mix it with about $\frac{1}{5}$ of its weight of fulphur and a little pitch, then to charge an earthen retort with the mixture, to keep it for fome time at a temperature not exceeding that of melted lead, and then to raife it by degrees till the zinc begins to be volatilized: the contents of the retort being now allowed to cool gradually, the purified zinc would be found at the bottom, covered by a fcoria of fulphuret.

If however the zinc is required of extreme purity, take the common fulphat of zinc (white vitriol of the fhops) diffolve it in hot water, and add a little fulphuric acid and granulated zinc, by this means the copper, arfenic, and the principal part of the iron will be precipitated. When the acid is faturated pour off the clear liquor, and evaporate it to drynefs; moiften the white falt thus procured with a little nitric acid, and heat it nearly to rednefs in a crucible; by this the refidue of the iron and manganefe will be reduced to the ftate of infoluble oxyd, and warm water will take up only the pure fulphat of zinc. This is to be decompofed by carbonat of ammonia, and the white precipitate thus obtained, after being wafhed and calcined, is to be mixed with about $\frac{1}{6}$ of charcoal, and reduced by diftillation in the ufual way.

§. 4. *Phyfical and Chemical Properties.*

The colour of zinc is bluifh-white with a high metallic luftre; its texture is between hackly and foliated, that is to fay, the plates of which it confifts inftead of being fmooth like thofe of bifmuth or antimony, are covered with a multitude of fmall points which render it peculiarly harfh to the touch. In thin plates it may be broken without difficulty, but in doing fo a kind of refiftance is perceived, as if the facets of which it is compofed adhered to each other not merely by the appofition of their furfaces, but by the mutual penetration of thofe little points with which, when feparated, they appear to be covered. The larger ingots cannot be broken but by means of iron wedges. Zinc at the common temperature poffeffes a moderate degree of ductility, and may be laminated by paffing through rollers into plates of confiderable thinnefs and elafticity. With care it may be drawn into wire, the tenacity of which,

according to Muschenbroeck, is equal to about 26 lbs. upon $\frac{1}{10}$ of an inch in diameter. If, however, zinc is hammered at about the temperature of 300° F. its malleability is greatly increased; it will now bear to be bent backwards and forwards several times before it breaks; its fracture is fibrous and steel grained; it may be reduced into thin leaves by lamination, and may be drawn into wire not exceeding $\frac{1}{100}$ of an inch in thickness, and possessing nearly the tenacity of silver.[b] The hardness of zinc is somewhat inferior to that of copper: its specific gravity varies from 6.8 to about 7.1; by hammering it is increased to 7.19. It yields easily to the file, but in a very short time entirely clogs up the teeth of this instrument, rendering it quite smooth. By friction, or even when kept in a moist warm hand for a short time, it gives out a very sensible metallic odour, somewhat resembling that of iron. When heated to 400° Fahr. and upwards, it becomes perfectly brittle, and in this state may be pulverized without difficulty in a heated mortar. At about 700° Fahr. it melts, and in a full red heat is volatilized. It crystallizes with difficulty into tetrahedral or compressed hexahedral prisms.

The action of air upon zinc at the common temperature is very slight; it acquires a very thin superficial coating of grey oxyd, which adheres to the metal and prevents any further change. But if the zinc is melted it soon becomes covered with a pellicle of grey oxyd, and this being removed as fast as it forms, the whole mass of metal is in no very long time entirely oxydated. If the grey oxyd thus formed is still further calcined at a red heat, it acquires a greenish-yellow colour, and increases in weight: by a white heat it runs into a compact yellow glass.

If zinc instead of being merely melted is ignited, it takes fire and burns rapidly, with an intense bluish-white flame of great brilliancy: as the combustion goes on, the metal is converted to a yellowish-white flocculent oxyd, so light as to be thrown up into the air by the force of combustion, a peculiar odour which has been likened to that of arsenic being given out. This sublimed oxyd is commonly known by the name of *Flowers of Zinc*, and in the writings of the older chemists by those of *Nihil album*, *Pompholix*, *Philosophical Wool*, &c. If this oxyd as soon as prepared is put into a dark place, it will be perceived to emit a bluish phosphoric light for the space of an hour or more. Another phenomenon which has probably some relation to the above is, that, if a filter be filled with flowers of zinc, and water repeatedly passed through them, they will appear superficially of a dazzling white, and internally of a pure sky-blue, which last however is replaced by the common yellowish tinge in proportion as it becomes dry. The flowers of zinc like the other oxyd are reducible by an intense heat into a yellowish glass.

The composition of the oxyds of zinc is by no means yet ascertained with the desired precision, we shall therefore state the results of all the experiments that have been made on this subject, with such observations as may suggest themselves.

1. According to Bergman,[c] 100 parts of zinc, after being dissolved in dilute sulphuric acid and precipitated by caustic soda, afforded 161 of oxyd dried at the temperature of boiling water; therefore 100 parts of oxyd are composed of 62 zinc and 38 oxygen. But the oxyd dried at this low temperature must necessarily retain a considerable portion of water; indeed it is by no means improbable that it would actually be in the state of hydrat, which, according to Mr. Smithson, is composed of 75 oxyd and 25 water. If the necessary correction be made upon this supposition, 100 parts of oxyd will consist of 83.3 zinc, and 16.7 oxygen.

2. According to Vauquelin,[d] (but from what particular experiments we are not informed) 100 parts of oxyd of zinc produced by calcination of the artificial carbonat, are composed of 69 of zinc and 31 of oxygen.

3. According to Clement and Desormes,[e] 14.36 parts of zinc heated red-hot in a coated glass tube, with a stream of air passing through it, afford 17.48 parts of a white oxyd, the composition of which therefore *per cent.* is 82.15 zinc, and 17.85 oxygen.

The same chemists found that 30 grammes of sublimed oxyd of zinc, by distillation with charcoal at a high heat were reduced to 21.82 grammes of metallic zinc, according to which 100 parts of sublimed oxyd consist of 72.4 zinc, and 27.6 oxygen. In this however the amount of zinc is very probably under rated, as several minute particles might remain unperceived in the charcoal.

It appears from another experiment of the above chemists, that the sublimed oxyd when exposed to a forge heat for a quarter of an hour loses about 7 *per cent.* and at the same time acquires a dull yellow colour; hence the compo-

[b] Phil. Mag. xxiii. p. 282. [c] Opuscula, ii. p. 392. [d] An. de Ch. xxviii. p. 47. [e] Ib. xxxix p. 32.

ſtion of this ſub-oxyd is 88 of zinc to 12 of oxygen.

4. Some experiments of Prouſt[f] on the ſame ſubject deſerve to be cited. According to this able chemiſt, 100 parts of zinc, by ſolution in nitric acid, and ſubſequent ignition afford 125 of yellowiſh oxyd. Alſo 100 parts of zinc when diſſolved in nitric acid and precipitated by carbonat of potaſh afford 180 of dry carbonat, which by calcination is reduced to 125 of mere oxyd. Hence according to both theſe experiments, oxyd of zinc is compoſed of 80 zinc and 20 oxygen.

5. According to Morveau the greeniſh oxyd formed by calcining the grey oxyd is compoſed of 85 *per cent.* zinc and 15 oxygen; and

6. According to Wenzel the moſt highly calcined oxyd of zinc conſiſts of 80 zinc and 20 oxygen, in which he perfectly agrees with Prouſt.

What concluſion can be drawn from theſe various reſults except the neceſſity of freſh experiments?

The mutual action of zinc and water is very conſiderable. If pulverized zinc be moiſtened with this fluid at the common temperature, the mixture in the ſpace of a few hours becomes black, increaſes in bulk, diſcharges hydrogen gas with a viſible efferveſcence, and at length is converted into a greyiſh-white oxyd. At a high heat the decompoſition of the water is much more rapid, as we learn from an experiment of Dr. Prieſtley's; this philoſopher having incloſed ſome zinc in a glazed earthen tube heated it red, and then paſſed ſteam over it; a large quantity of hydrogen was produced, and the zinc was converted into a dark coloured ſemi-tranſparent glaſs.

The action of the alkalies is very ſtriking, and was firſt obſerved with accuracy by De Laſſone[g]. If filings of this metal are immerſed in ſtrong and perfectly cauſtic liquid ammonia and a gentle heat applied, the mixture ſoon becomes turbid and milky, a copious efferveſcence, probably of hydrogen gas, takes place, the odour of which is ammoniacal and alliaceous, the zinc is by degrees diſſolved, and the ſolution, during the efferveſcence, becomes of a deep black colour. The ſolution being completed, a little black powder falls to the bottom, and the liquor after filtration is perfectly clear and of a yellow colour. If the zinc employed is in the ſtate of ſublimed oxyd inſtead of metallic filings, the liquor becomes ſenſibly hot, no gas is given out, and the ſolution is completed in a conſiderably ſhorter time than was required in the former caſe. Ammoniuret of zinc concretes by cooling and evaporation into feathered cryſtals, which are permanent in the air. If the ammonia is ſaturated with zinc the ſolution is in part decompoſed by water, a white oxyd being precipitated; this however may be prevented by pouring in a little ammonia previous to the addition of water. No viſible change is produced by the addition of cauſtic fixed alkali, but all the acids decompoſe it, throwing down the metallic oxyd: with tincture of galls a deep grey precipitate is produced: if a plate of copper is immerſed in the ſolution the zinc is in part precipitated and the copper is diſſolved, tinging the ammonia of a blue purple colour.

The cauſtic fixed alkalies act upon metallic zinc in nearly the ſame manner as ammonia does, but according to De Laſſone they are incapable of diſſolving the ſublimed oxyd. This is remarkable, for it is certain from the experiments of Vauquelin and others that the oxyd precipitated from the ſalts of zinc is perfectly ſoluble in either potaſh or ſoda.

Owing to the powerful affinity of zinc for oxygen it combines with the acids with great readineſs, forming a numerous claſs of ſalts, many of which are of importance.

Concentrated ſulphuric acid when aſſiſted by heat diſſolves zinc either in the metallic ſtate, or in that of oxyd, ſulphurous acid gas being given out in the former caſe. If the acid is diluted with water it acts rapidly on zinc at the common temperature, an abundance of hydrogen gas being given out. The ſolution when completed, and filtered to ſeparate a ſmall portion of inſoluble black matter, affords, by evaporation and cooling, *ſulphat of zinc* in the form of compreſſed tetrahedral or hexahedral priſms terminated by tetrahedral pyramids. This ſalt if free from iron (which however it ſeldom is without particular precautions) is perfectly colourleſs and tranſparent, it is moderately hard, and has a diſagreeably ſtyptic metallic flavour which remains long on the palate. Its ſp. gr. is 1.912. It is ſoluble in about $2\frac{1}{2}$ parts of water at 60°, and in a much ſmaller proportion of boiling water. It effloreſces by expoſure to the air. In a dry heat it firſt melts in its water of cryſtallization, and is reduced to an opake maſs, afterwards by ſtrong ignition it parts with moſt of its acid in the form of ſulphurous acid gas. It is decompoſed in the moiſt way, with precipitation of its oxyd

[f] An. de Ch. xxxv. p. 53.

[g] Mem. Sci. 1775.

by all the alkalies, either cauſtic or carbonated, and by all the alkaline earths. The proportion of its component parts is very variouſly ſtated. According to Bergman[h] 100 parts of the cryſtallized ſalt loſe 40 by gentle calcination, which are therefore water; the reſidue after being kept white hot for three hours was reduced to 20 parts of a greeniſh-grey colour which was oxyd of zinc, the acid having been driven off. From theſe data ſulphat of zinc conſiſts of

20. Oxyd of zinc
40 Sulphuric acid
40 Water

100

But according to Mr. Kirwan[i] 100 parts of ſulphat of zinc by a heat of 376° loſe 39 which are water, and a ſimilar quantity of the ſame ſalt afforded with muriat of barytes 61.24 of ignited ſulphat of barytes. But the compoſition of ſulphat of barytes is variouſly ſtated. Klaproth, Black and others reckoning the amount of acid in this ſalt to be 33.33 *per cent.* whereas Mr. Chenevix eſtimates it at no more than 23.5. Hence the compoſition of ſulphat of zinc as found by Mr. Kirwan's analyſis may be reckoned at

39. Water
20.4. or 14.3 Sulphuric acid
40.6. or 46.7 Oxyd of zinc

Mr. Smithſon[k] again, from ſome ſimple and apparently accurate analyſes reckons the component parts of dry ſulphat of zinc to be

50 Sulphuric acid
50 Oxyd

100

The ſalt called in commerce *White vitriol* is an impure ſulphat of zinc of a bluiſh-white colour with ochery ſtains externally; it has a granular cryſtalline texture like loaf ſugar, and is in irregular lumps and maſſes. It is prepared largely at Rammelſberg and elſewhere in Germany by roaſting blende and then expoſing it to the air; the ſulphats of zinc, lead, iron and copper that are thus formed, are ſeparated from the earthy parts by lixiviation, and the liquor being boiled down till a ſtrong ſaline pellicle forms on its ſurface is let out into cryſtallizing vats where it concretes into hard granular maſſes. The Engliſh white vitriol is prepared for the moſt part by direct ſolution of metallic zinc in ſulphuric acid, and is therefore purer than the foreign, though it ſtill contains a very notable quantity of iron. Both kinds may be conſiderably, though not entirely, purified by ſolution in water, and then abandoning the liquor to ſpontaneous evaporation in an open veſſel containing ſome granulated zinc: the ſulphat of lead will ſubſide to the bottom, and other foreign ſulphats will be decompoſed by the metallic zinc. The ſaline maſs when dry is to be lixiviated with cold water and the clear filtered ſolution, after due evaporation, will afford regular cryſtals of ſulphated zinc.

Sulphite of zinc is prepared by putting ſome oxyd of zinc and water into a Woulfe bottle, and throwing in ſulphurous acid gas till the oxyd is diſſolved. The ſalt thus formed cryſtallizes by gentle evaporation. It has a ſtyptic ſulphureous flavour: it is eaſily ſoluble in water, but not at all ſo in alcohol: it is decompoſed by the other acids with efferveſcence owing to the eſcape of ſulphurous acid gas; it forms white precipitates with the alkalies which are entirely re-ſoluble in cold dilute ſulphuric acid: by expoſure to the air it is ſoon converted into the ſulphat.

If ſulphurous acid is digeſted upon metallic zinc inſtead of the oxyd, an immediate and rapid action takes place between them; much heat is diſengaged, ſulphuretted hydrogen gas is produced, the fluid becomes of a turbid brown or yellow colour, but grows clear in proportion as the ſaturation advances. The fluid thus produced has a remarkable pungent ſtyptic and ſulphureous flavour; when gently evaporated it becomes thick like ſyrup, and then depoſits acicular tetrahedral priſms terminated by very acute tetrahedral pyramids; theſe when expoſed to the air become efflореſcent, and are ſlowly decompoſed into a mixture of ſulphat of zinc and ſulphur. Before the blow-pipe this ſalt gives out a vivid light like zinc in combuſtion, and throws out on every ſide arboreſcent and tubercular ramifications. The ſulphuric and muriatic acids decompoſe it with effervеſcence, ſulphurous acid gas being given out, and a yellowiſh-white powder being precipitated. Nitric acid alſo ſets at liberty ſulphurous acid, and throws down a flocculent ductile and adheſive precipitate which is ſulphur. When diſtilled *per ſe* in a retort it affords water, ſulphurous and ſulphuric acids, ſublimed ſulphur, and there remains behind oxyd of zinc with a little ſulphat. By digeſtion with alcohol it is

[h] Opuſcul ii p. 328. [i] On real Acid, p. 69. [k] Phil. Tranſ. 1803. p. 23. [l] Fourcr. Syſt. des Connaiſſ. v. p. 380.

decomposed into two portions, of which one is insoluble and the other readily soluble in this fluid. The former is sulphite of zinc already mentioned; the latter is *Sulphuretted sulphite of zinc*; it gives out on the addition of sulphuric acid both sulphur and sulphurous acid, and to this are obviously owing all those properties of the compound salt by which it is distinguished from the pure sulphite.

Nitric acid, moderately strong, is said to be capable of inflaming zinc filings, and even when much diluted acts on this metal with great violence, and with a copious disengagement of nitrous gas and nitrous oxyd. The solution is generally of a pale greenish yellow colour, and is highly caustic: by evaporation and cooling it deposits *Nitrat of zinc*, in compressed, striated, tetrahedral prisms, terminated by tetrahedral pyramids. The specific gravity of this salt is 2.09. It absorbs moisture from the air, and deliquiates; it is readily soluble both in water and alcohol. When laid on hot coals it melts and detonates rather feebly, giving out a faint reddish flame; when heated *per se* in an earthen crucible it is decomposed, giving out nitrous and oxygen gasses, and the metal remains behind in the state of yellowish oxyd.

Muriatic acid acts with much rapidity on zinc, hydrogen gas of very considerable purity being given out. The solution is clear and colourless: by evaporation and cooling it gelatinizes, but cannot be made to crystallize. When distilled, there first arises a little strong and fuming muriatic acid, and then the *muriat of zinc* itself passes over in a half solid consistence, on which account it is often called *butter of zinc*. This sublimed muriat is of an opake white colour, and consists of minute prismatic crystals. It is fusible by a gentle heat, absorbs moisture from the air, and assumes a gelatinous consistence; it is not decomposable by mere water, and is very soluble both in this fluid and in alcohol: the alkalies decompose it, throwing down a beautifully white oxyd.

Oxymuriatic acid gas inflames filings of zinc that are thrown into it, and the result is a muriat of zinc not differing from the preceding.

Liquid phosphoric acid attacks zinc with effervescence, hydrogen gas being given out: the *phosphat of zinc* thus produced forms a white insoluble powder. This salt may also be procured by adding to the sulphat, nitrat, or muriat of zinc, any of the neutral phosphats.

Water impregnated with carbonic acid acts readily on either metallic zinc or its oxyds. The solution by exposure to the air becomes covered with an iridescent pellicle of oxyd. The most ready way however of obtaining it is by the decomposition of the sulphat, or almost any of the other salts, by means of a carbonated alkali; a dense white precipitate is thus formed, which, when well washed and dried, is pure *Carbonat of zinc*. According to Bergman, 100 parts of metallic zinc, when dissolved in an acid, and precipitated by carbonated soda, afford 193 parts of carbonat; but Bergman's precipitates were dried only at 212°, and therefore probably retain d a considerable portion of water. According to Proust,[m] 100 parts of zinc afford by solution in nitric acid and precipitation by carbonated potash, 180 parts of dried carbonat; in which result the experiments of Dizé and of Hecht, exactly coincide: these 180 parts are reduced by calcination to 125 of mere oxyd, hence the component parts of this salt when thoroughly dried, are

55	Zinc
14	Oxygen
31	Carbonic acid
100	

The fluoric and boracic acids act upon zinc, the former rapidly, the latter with difficulty, but the properties of these salts have not been examined.

If zinc filings are digested in distilled vinegar, they dissolve in this fluid with effervescence, and the result is *acetat of zinc*; according to De Lassone, 12 ounces of vinegar take up only 2 drams of zinc; if however radical vinegar or acetic acid be employed, the above quantity of metal will be taken up by ¼ of an ounce of acid. Flowers of zinc are also soluble with ease in acetic acid, a considerable degree of heat being excited during the process. The taste of this salt is bitter and metallic. It crystallizes in thin and shining hexagonal and rhomboidal plates: when heated *per se* in a retort a part sublimes with little alteration, except that it is whiter than before. When laid on hot coals it burns with a blue flame. It is readily soluble in water and is decomposable by the alkalies, by the mineral acids, and by all those that form with zinc an insoluble salt.

In consequence of the medical application of acetat of zinc, the following facts may be of use to the practitioner. The specific gravity of a saturated solution of acetat of zinc made by digesting the crystallized salt in distilled vinegar,

[m] An. de Chim. xxxv. p. 53.

is = 1.055. Of this ſolution 900 grains contain 53 grains of dry, or 82.6 grains of cryſtallized acetat. One ounce by meaſure of the ſolution, weighs 506 grains, and contains 29.8 grains of dry, or 46.5 grains of cryſtallized ſalt.

The ſuccinic and benzoic acids form cryſtallizable ſalts with zinc, the properties of which have not yet been examined.

Oxalic acid diſſolves zinc with conſiderable effervescence, and a white powder ſubſides, which is *Oxalat of zinc*. It may alſo be prepared by adding oxalic acid to the ſulphat, muriat, or nitrat of zinc. It is very ſparingly ſoluble in water, unleſs an exceſs of acid is preſent; it contains, according to Bergman, 75 *per cent.* of metal.

Citric acid in like manner diſſolves zinc with effervescence, and minute cryſtalline grains are depoſited of *Citrat of zinc*: they have a ſtyptic and metallic taſte, are little ſoluble in water, and conſiſt, according to Vauquelin, of

50	Citric acid
50	Oxyd of zinc
100.	

The ſalts formed by the other vegetable acids and zinc are very little known.

There are two triple ſalts of zinc; the one formed by digeſting filings of the metal in muriat of ammonia, the other by employing a ſolution of acidulous tartrite of potaſh (cream of tartar). Neither of theſe ſalts is cryſtallizable, nor are they decompoſed by the pure or carbonated alkalies.

The neutral and earthy ſalts are many of them decompoſable by zinc. Nitre and the other ſalts belonging to that genus detonate rapidly when heated with zinc. The alkaline ſulphats are converted into ſulphurets; and muriat of ammonia is decompoſed, ammoniacal gas being given out, and the acid combining with the oxyd of zinc.

Very little affinity appears to exiſt between zinc and ſulphur. As long as the former retains its metallic ſtate it cannot be made to combine with ſulphur by fuſion or in any other way. If zinc filings and flowers of ſulphur be made into a paſte with water, a decompoſition of this latter will take place, the metal will be oxydized, hydrogen gas will be given out, but the reſidual maſs will be a mere mixture of ſulphur and oxyd of zinc. A mixture of flowers of zinc and ſulphur combine by fuſion into a yellowiſh-brown maſs, which has been compared to blende. The alkaline ſulphurets when melted with oxyd of zinc and afterwards diſſolved in water, let go the greateſt part of the oxyd unaltered, they retain however a very ſmall portion. Water ſaturated with ſulphuretted hydrogen decompoſes after ſome time the ſalts of zinc, forming a yellow precipitate, which is probably a hydroſulphuret. Prouſt propoſes the uſe of this re-agent to purify zinc from copper and iron: the mixture being diſſolved in dilute nitric acid and duly neutralized, the hepatic water is to be carefully added till it ceaſes to produce a black precipitate; this is hydroſulphuret of copper, and may readily be ſeparated by filtration; to the clear liquor now add more of the hepatic water as long as any yellow precipitate falls down; this is the zinc: the iron remains in the ſolution.

Hydrogen appears capable of taking up a minute portion of zinc when it is produced by the rapid action of dilute ſulphuric acid on this metal: this hydrogen burns with a ſomewhat brighter flame than common hydrogen.

Zinc combines readily with phoſphorus, as Pelletier has ſhown, by adding to zinc, when in fuſion and covered with oil to prevent oxydation, a few pieces of phoſphorus. The *phoſphuret of zinc* thus produced is of a whitiſh colour and a metallic luſtre not unlike lead. It is ſomewhat malleable, exhales a phoſphoric odour by friction, and in a high heat burns like common zinc. Phoſphorus alſo combines with the oxyd of zinc: if a mixture conſiſting of 6 parts oxyd of zinc, 6 parts vitreous phoſphoric acid, and 1 part of charcoal powder, is ſtrongly heated in an earthen retort, a ſilvery-white vitreous matter is ſublimed, which, according to Pelletier, is phoſphorized oxyd of zinc.

Zinc combines with many of the other metals, forming alloys, the greater number of which have been already deſcribed.

Zinc and antimony unite by fuſion, forming a compact homogeneous brittle maſs, of an aſh-grey colour, and of leſs denſity than the mean of its ingredients.

Zinc with copper forms ſeveral important alloys, for an account of which ſee Brass and Copper, alloys of.

Zinc and Gold; ſee Gold, alloys of

Zinc unites with iron by fuſion, but not very eaſily on account of its volatility; the reſult is a hard ſomewhat malleable alloy of a white colour approaching to that of ſilver. Iron plate may alſo be covered with zinc in the ſame manner as it is with tin.

Zinc and Lead; ſee Lead, alloys of.

* Zinc and tin combine by fusion, forming a ductile alloy, harder than zinc and of a better colour.

Zinc and Mercury; see MERCURY, alloys of.

Zinc forms with silver a bluish-white brittle alloy of a granular texture.

The uses of zinc in its various forms are considerable. In its metallic state it is employed by the Chinese for coins, and has been proposed in this country as a substitute for lead and tin in forming and lining various culinary vessels: this however is extremely injudicious as zinc is remarkably soluble in all acids, and all its salts are violent emetics. In combination with copper it forms brass and all the useful and ornamental gold coloured alloys. Its sublimed oxyd has been used in oil painting as a substitute for white lead: it has not indeed the density of common white paint, and therefore one or two more coatings are required of the former than of the latter, but in return it is not liable to be blackened by sulphureous vapours, and is entirely free from the deleterious effects of lead paint. Of the salts of zinc the sulphat is largely used by varnishers, &c. to make oil drying, and this together with the acetite is employed in medicine. In the laboratory the chief use of zinc is to procure hydrogen gas by the solution of it in the sulphuric or muriatic acids.

ZIRCON. Jargon or Jargoon. Hyacinth.

Werner and his disciples make two separate species of the zircon or jargon, and hyacinth; but from the analyses of Klaproth and Vauquelin, and the crystallographical researches of Hauy, it is evident that the two species ought to be consolidated into one. The colour of this mineral is pale greyish-white, smoke-grey, and greenish-grey, leek-green and olive-brown, also pale wine-yellow, orange-yellow, bluish-red, blood-red, and reddish-brown. It occurs in small rounded pieces and crystallized. Its primitive form is an octohedron with isosceles triangular faces: the angle formed at the common base of the pyramids is $= 82° : 50'$. It presents also the following varieties of crystallization.

1. The rhomboidal dodecahedron.
2. The same as the preceding except that the sides of the prism are hexagons instead of rhombs.
3. Var. 2. with the common edges of the prism and terminating pyramids truncated.
4. Var. 2. with the lateral edges of the prism truncated.
5. A combination of the two preceding varieties, that is var. 2. with all the edges of the hexagonal faces truncated.
6. A strait tetrahedral prism terminated by tetrahedral pyramids.
7. The preceding with the solid angles at the base of the pyramids truncated.
8. Var. 6. with both the solid angles and common edges of the prism, and terminating pyramids truncated.

The crystals are small and very small; externally they are smooth and shining; internally both the crystals and rounded pieces have a brightly shining lustre, between adamantine and vitreous. The fracture is foliated passing into flat conchoidal: the fragments are indeterminate and sharp edged. It varies from translucent to transparent, and is doubly refracting in a high degree. It is hard enough to scratch quartz, though with difficulty. It is brittle and easily frangible. Sp. gr. 4.38—4.62.

It loses its colour but is infusible *per se* before the blow-pipe. The following are the analyses that have been made of this mineral.

Jargon of Ceylon. Klaproth	*Hyacinth of Ceylon.* Klapr.	*Do.* Vauquelin	*Hyacinth of Expailly.* Vauquel.	
68.	70.	64.5	66.	Zircon
31.5	25.	32.	31.	Silex
0.5	0.5	2.	2.	Oxyd of Iron
100.	95.5	98.5	99.	

It occurs in the beds of rivers in Ceylon mixed with magnetic sand, ruby, tourmaline, sapphire, &c. also in the sand of the brook Expailly in Auvergne; near Meronitz and Hohenstein in Saxony; at Schelkowitz in Bohemia imbedded in trap; and at Friedrichschwarn in Norway.

The yellow and smoke coloured varieties are called by the jewellers jargoons, and are not unfrequently passed off as diamonds: the orange-red varieties are called hyacinths. The commercial value both of one and the other is considerably inferior to that of the diamond and all the oriental gems.

ZIRÇON (Earth).

This earth was first discovered by Klaproth[a], and its leading properties have since been carefully investigated by Vauquelin[b]. It is obtained from the jargon or hyacinth (see the preceding article) by the following process. The mineral being very accurately pulverized is to be mixed with six times its weight of perfectly caustic potash dissolved in a little water. The mass being evaporated to dryness in a silver crucible is to be kept at a low red heat for two hours: after this being allowed to cool it will be found strongly adherent to the crucible, and must accordingly be covered with 10 or 12 times its weight of water, to which must then be added a sufficiency of muriatic acid in order to supersaturate the alkali. By a gentle digestion the whole of the mass will be dissolved, and the clear solution is to be evaporated slowly to dryness, stirring it about all the time to facilitate the separation of the silex. The residue of the evaporation is now to be digested with a moderate quantity of water slightly acidulated by muriatic acid, which will take up the zircon and oxyd of iron, leaving the silex behind. This evaporation and re-solution in very dilute muriatic acid is to be repeated two or three times that every particle of silex may be separated. To the muriatic solution is now to be added carbonat of ammonia, which will at first occasion an abundant precipitate, but by adding an excess of the alkali the whole of the zircon will be re-dissolved and the oxyd of iron will fall to the bottom. The clear filtered liquor is to be boiled for two or three hours, by which the excess of ammonia will be driven off, and the zircon will be deposited in the state of carbonat, and in the form of a white powder. This powder being washed and properly dried is afterwards to be calcined, by which about 43 *per cent.* of water and carbonic acid will be driven off, the remainder being pure zircon.

Calcined zircon is of a white colour, is rough to the touch, is insipid and insoluble in water. Its sp. gr. is $= 4.3$. After being exposed to an intense heat in a charcoal crucible it acquires a grey colour, a vitreous fracture, and is hard enough to give fire with steel. When precipitated by caustic alkali from its acid solutions it retains about $\frac{1}{4}$ of its weight of water, in consequence of which, after drying in the air, it acquires the semi-transparence of horn, a yellow colour, and a conchoidal vitreous fracture. Sulphuric acid combines with zircon, forming an insipid pulverulent salt, insoluble in water, but readily decomposable by heat, and even by long boiling in water. If this insoluble sulphat is digested in dilute sulphuric acid it dissolves, and by cautious evaporation may be brought to crystallize in needles: in this state it is decomposable by water, the excess of acid being abstracted. The alkalies and alkaline earths decompose sulphat of zircon, but the nitric and muriatic acids do not, though they dissolve it readily. When heated in a retort with charcoal its acid is decomposed, and by digesting the sulphuret thus formed in water it dissolves, and the solution, by evaporation, affords colourless transparent crystals; their flavour is strongly sulphureous, but their other properties have not been ascertained.

Nitric acid combines easily with zircon, especially if this latter is moist and recently precipitated. This salt has always an excess of acid: it is not crystallizable but is reduced by evaporation to a viscid gummy consistence: to the taste it is styptic and astringent. It is decomposed by sulphuric acid, an insoluble sulphat being precipitated. Gallic acid occasions in it a white precipitate, as also does hydro-sulphuretted water and hydro-sulphuret of ammonia.

Muriatic acid readily takes up zircon from the carbonat, but does not touch this earth after it has been calcined. It is soluble in water and alcohol, and by evaporation may be obtained in needle-shaped crystals. It is decomposed by the same substances as the nitrat, and affords white flocculent precipitates with the phosphoric, nitric, oxalic, and saccholactic acids.

Zircon is insoluble in the moist way by the fixed alkalies either caustic or carbonated, but is taken up (as we have already mentioned) by carbonated ammonia.

When mixed with silex and alumine it is fusible by a high heat into a white porcellanous mass.

In its affinities for the acids it is decidedly inferior to the alkalies, the alkaline earths, and even to alumine.

Neither the earth nor its salts are made any use of.

[a] Analyt. Ess. I. p. 175. [b] Journ. des Mines, No. 25. p. 97.

ADDENDA.

CERIUM*.

The substance called cerium by Hisenger and Berzelius, two Swedish chemists, and ochroïtes by Klaproth, is an earthy powder of a white, yellowish, or reddish-brown colour, and is considered by the former, with whom Vauquelin also coincides, as the oxyd of a new metal, while it is regarded by Klaproth as an earth, which, like yttria, holds a sort of middle rank between the proper earths and metallic oxyds. Upon the whole we incline to the opinion of Vauquelin, and shall therefore in the following article consider cerium as a metallic substance.

§ 1. *Ores.*

Sp. 1. Cerite. *Ochroïte* of Klaproth. *Reddish Tungsten* of Scheele. *False Tungsten* of Elhuyars.

Its colour is between rose and flesh-red, reddish-brown and clove-brown; it occurs massive or disseminated. Its fracture is compact splintery. Internally it is shining. It varies from semi-transparent to opake. It scratches glass, and gives fire with difficulty when struck against the steel. It is brittle and easily frangible. Sp. gr. 4.53—4.66.

Before the blow-pipe it is infusible, but becomes friable, and acquires a brown colour according to Klaproth, but a yellow one according to Vauquelin. It is very sparingly soluble in glass of borax.

Two varieties appear to have been analysed: that by Klaproth was opake, and became brown by calcination; that by Vauquelin was semi-transparent and became yellow by calcination. The results are as follow:

Klapr.		Vauq.	
54.5	—	63.	Oxyd of Cerium
34.	—	17.5	Silex
4.	—	2.	Oxyd of Iron
0.	—	4.	Lime
5.	—	12.	Water
97.5		98.5	

It occurs at Bastnaës, near Riddarhyttan, in Sweden, in gneiss, accompanied by copper pyrites, bismuth, and molybdena, hornblende, and actynolite.

§. *Analysis.*

The analysis of cerite is upon the whole best conducted in the following way.

a. Having minutely pulverized the ore, weigh it, then ignite it and weigh it again; the difference may be set down as the amount of *water*.

b. Digest the calcined ore in repeated portions of nitro-muriatic acid, and when nothing further is taken up fuse the residue with caustic potash; then dissolve out the mass by muriatic acid, evaporate to dryness, and digest again in very dilute muriatic acid; the insoluble residue is *Silex*.

c. Add together the muriatic and nitro-muriatic solutions, and decompose the whole at a boiling heat by saturated carbonat of potash. Redissolve the whole in as little muriatic acid as possible, heat the solution to drive off the last remains of carbonic acid, and add perfectly caustic ammonia till there is an evident excess. Separate the precipitate and add to the clear liquor as much muriatic acid as will saturate it, and then throw down from it the *Lime* in the state of carbonat, by means of a mild alkali.

d. The ammoniacal precipitate consisting of the oxyds of cerium and iron, is to be dissolved in muriatic acid, and liquid hydrosulphuret of potash is to be dropped in till the precipitate, which at first will be greenish, becomes white. The clear liquor being separated and treated with carbonat of potash, affords a white precipitate, which is carbonat of cerium.

e. The greenish precipitate is to be dissolved in as little muriatic acid as possible, and the solution being neutralized by an alkali to the point of precipitation, sulphat of soda is to be added, which will throw down a sulphat of cerium. The residual fluid being then decomposed by ammonia deposits oxyd of *Iron*.

f. The sulphat of cerium (*e*) is now to be boiled with thrice its weight of carbonated soda, by which it will be converted into carbonat, which is to be dissolved in dilute muriatic acid, and again precipitated by carbonat of potash or of soda.

g. The carbonats of cerium (*d* and *f*) are now to be calcined, by which the pure brown oxyd of *Cerium* will be obtained.

* Nich. 8vo. viii. p. 207. An. de Chim. liv. p. 28.

§ 3. *Physical and Chemical Properties.*

Pure cerium does not appear to have been yet obtained in the metallic form; in Klaproth's experiments the oxyd when inclosed in a charcoal crucible, and subjected to the intense heat of a porcelain furnace underwent no alteration. Vauquelin, however, by mixing the tartrite of cerium with a little oil, lamp-black and borax succeeded in obtaining a few minute globules of a metallic appearance, which appeared to be an alloy of cerium and iron.

The precipitate from any of the salts of cerium by means of a caustic alkali is the metal in its lowest state of oxydation. Its colour is white; by exposure to the air it acquires a yellowish tinge in its progress towards the state of perfect oxyd, but as it absorbs at the same time carbonic acid it cannot by this process arrive at its ultimate term of oxydation. When exposed to the blow-pipe it passes rapidly into perfect oxyd, and acquires a reddish-brown colour, but undergoes no further change. When mixed in small proportion with borax it forms a greenish-yellow transparent globule, which, by the exterior flame, becomes blood-red, and by long continuance of the interior flame becomes colourless.

The fixed alkalies when digested with heat on the brown calcined oxyd change its colour to white, and bring it to the lowest term of oxydation, but do not dissolve any of it. Ammonia has a similar effect on the uncalcined oxyd.

Sulphuric acid, diluted with four times its weight of water and digested on the per-oxyd of cerium first communicates to it a brilliant crystalline appearance, and at length, if the acid is considerably in excess, forms a complete solution of it: this solution, by very gentle evaporation, deposits minute orange coloured crystals, sparingly soluble in water, and of a sweet acidulous taste. If the carbonat or sub-oxyd of cerium, is employed, the result is a very pale rose coloured solution which crystallizes without difficulty: this latter sulphat contains no excess of acid, and has merely a saccharine taste. The same salt may be produced by double affinity; if sulphat of soda is added to the nitrat or muriat of cerium a crystalline precipitate falls down, which is the salt in question.

Nitric acid, assisted by heat, dissolves easily either of the oxyds, forming a yellow solution, which cannot be made to crystallize; the salt however may be obtained by gentle evaporation. It has a somewhat pungent saccharine taste; is soluble in twice its weight of alcohol, and when exposed to heat it melts, is decomposed, and a brick-red oxyd remains behind.

Muriatic acid when digested on the per-oxyd of cerium exhales an abundance of oxy-muriatic acid gas; the oxyd is by degrees dissolved, forming a pale rose coloured solution, which, when evaporated to the consistence of a thick syrup, deposits a confused mass of crystals. This muriat has a sweetish flavour, is soluble in three or four times its weight of alcohol, and when decomposed by dry distillation, there comes over oxymuriatic acid, and a white sub-oxyd of cerium remains in the retort.

Any of the preceding salts are decomposable by the alkaline carbonats, succinats, phosphats, tartrites and oxalats forming white precipitates, the properties of which have not yet been investigated.

Neither tincture of galls nor hepatic water produce any decomposition of the above salts of cerium, but the liquid alkaline hydro-sulphurets throw down a yellowish-white precipitate; and prussiat of potash a milk-white one, provided no iron is present.

No use whatever has been made of cerium in any form.

SCHORL, (*omitted by mistake in its proper place*). Tourmaline. Cockle *of the Cornish miners.*

Werner divides this mineral into two sub-species, one of which he calls the black and the other the electric schorl. But as both of them are electrical, and as the differences between them are very trivial, we have thought best to follow the example of Hauy, and consider them as forming only one species.

The colour of this mineral is greyish-white; leek, olive, and pistachia green; liver-brown, yellowish and reddish-brown; hyacinth-red, crimson-red; violet-blue, sky and indigo-blue; velvet-black. It occurs in mass, disseminated, in rolled pieces and crystallized. Its primitive form is an obtuse rhomboid, the larger plane angles of which measure 113° 34′ 41″. The actual forms that it presents are the following.

1. A nine-sided prism, terminated at one extremity by six, and at the other by three facets. Of the six facets, three are hexagons, and three triangles.

2. A twelve-sided prism terminated at each extremity by the same number of facets as the preceding. Of the six facets, three are heptagons, and three trapeziums.

3. A nine-sided prism, terminated by the same number of facets as the preceding. Of

the six facets, three are heptagons, and three rhombs.

4. A nine-sided prism, terminated as above. Of the six facets, the three larger are hexagons, and the three smaller irregular heptagons.

5. A nine-sided prism, terminated at one extremity by seven, and at the other by three facets. Of the seven, six are alternately rhombs and parallelograms surrounding an equilateral triangle.

6. A nine-sided prism, terminated as the preceding. Of the seven faces, six are alternately triangles and pentagons surrounding a triangle.

7. A twelve-sided prism, with nine faces on each summit.

8. A nine-sided prism, with nine faces on one summit, and three on the other. Of the nine faces, three are rhomboidal, and form the terminating pyramid, the other six are formed by truncatures of the common base of the pyramid and prism.

9. A nine-sided prism, one of the summits of which is unknown, the other is a pyramid composed of three lengthened hexagons with two trapeziums intervening between each.

10. A nine-sided prism, one of the summits of which is unknown; the other is composed of 15 faces, viz. three pentagons, three triangles, three rhombs, and six parallelograms.

11. A twelve-sided prism, one of the summits of which is unknown, the other is composed of 19 facets.

12. A twenty-four sided prism, one of the summits of which is unknown, the other is composed of six facets, alternately large and small.

The prisms are generally long in proportion to their thickness, and longitudinally striated. The internal lustre is more or less shining, between vitreous and resinous. The longitudinal fracture is conchoidal, passing in the black varieties to coarse-grained uneven; the cross fracture has a tendency to foliated. It varies from translucent to opake. Its hardness is about equal to that of quartz. It is easily frangible. Sp. gr = 3.09—3.15.

Before the blow-pipe it is fusible by itself, without much difficulty. By friction it exhibits the vitreous electricity at each extremity; by heating, one end exhibits the vitreous, and the other the resinous electricity. The following are the principal analyses that have been made of it.

Black S. in mass.	D° Crystallized.	Tourmaline from Tyrol.	D° from Ceylon.	D° from Brasil.	Green D° from Brasil.
Gerhard		Bergman			Vauquelin
40.	38. Silex	40.	37.	34. Silex	40. Silex
25.	20. Alumine	42.	39.	50. Alumine	39. Alumine
15.	20. Lime	12.	15	11. Carb. Lime	3.84 Lime
18.	19. Iron and Manganese	6.	9.	5. Ox. Iron	12.5 Ox. Iron
					2. Ox. Manganese
98.	97.	100.	100.	100.	97.34

Schorl occurs in primitive rocks, especially in gneiss and granite, in micaceous and argillaceous schistus. It often is imbedded in quartz, but never, we believe in felspar. The opake black varieties with a granular fracture are called schorl, the others are called tourmaline.

Tourmaline is found in Ceylon, Madagascar, Daouria, Ava, Brasil, Spain, Switzerland, Sweden, Norway, France, Scotland, and Saxony. Schorl is more abundant, in Europe at least, than tourmaline is, and is found in most of the granitic and micaceous districts.

Tourmaline is sometimes cut into ring-stones, but its commercial value is very small.

APPENDIX, No. 1.

DESCRIPTION OF THE CHEMICAL APPARATUS MOST FREQUENTLY USED FOR GENERAL PURPOSES, WITH REFERENCE TO THE PLATES.

ACID-HOLDER. Pl. I. Fig. 12—VI. 66. This is a ſmall glaſs phial, the mouth of which is cloſely fitted into and inverted over the neck of a retort or other veſſel, and is furniſhed with a glaſs ſtop-cock. Its uſe is to drop any acid or other liquor gradually into a retort or other veſſel in which any proceſs is going on, without admitting the external air or deranging any other part of the apparatus. The quantity of acid dropped in is regulated by the ſtop-cock.

As the common acid-holders (Fig. 12) have no communication with the external air, it is difficult entirely to regulate the fall of the acid, on which account we have given Mr. Pepys's improvement to it (Fig. 66) that has another glaſs ſtopper at the upper end, by opening which the dropping of the acid may be completely regulated.

ADOPTER. Pl. I. Fig. 3.

This is a hollow glaſs veſſel of the form of a ſpindle, the upper part of which *receives* the beak of a retort, and the lower part *enters* the neck of a receiver, as ſhewn in the plate referred to.

Its uſe is to increaſe the diſtance between the two, and thus to facilitate the condenſation of the heated vapour, which is often of importance where the vapour is not readily condenſible, and the receiver liable to be heated by the fire.

AIR-HOLDER. See Gazometer.

AIR-FURNACE. See Furnace.

ALEMBIC. See Distilling Apparatus.

ALUDEL. Pl. II. Fig. 36.

This is an old apparatus for ſublimation, conſiſting of any number of earthen pots of the form repreſented, the upper fitting into the lower, and the loweſt of all entering into a round crucible or any other convenient veſſel in which the ſubſtance to be ſublimed is heated. Aludels however are now almoſt entirely diſuſed, almoſt all ſublimations being performed only in two veſſels, viz. the lower one in which the material is heated, and the upper, which receives the ſublimate; it having been found that where aludels were employed, almoſt all the ſublimate that could be collected at all, was detained in the firſt veſſel; and another inconvenience of aludels is that the ſublimed matter if accidentally detached is very liable to fall down again into the crucible.

AREOMETER. See Specific Gravity.

ATHANOR. See Furnace.

BALLOON. Pl. II. Fig. 39. *c*.

This is ſimply a large glaſs globe with a plain neck of moderate length, and anſwers a variety of purpoſes.

BALNEUM.
BATH. } A bath or balneum in chemiſtry is (like a common warm-bath) an intermede by which any body immerſed in it, totally or partially, may be heated more uniformly and moderately than from direct contact with the fire. The common balnea in chemiſtry are veſſels filled either with water or ſand and ſet immediately over the burning fuel.

The Common Water Bath cannot receive a greater heat than 212°, and it will not raiſe the temperature of any ſubſtance immerſed in it, quite ſo high. It is ſometimes attached to an alembic. (Pl. II. Fig. 34. *b*.)

It is particularly uſeful in evaporations of animal or vegetable matter, where the product would be altered and ſpoiled by a ſcorching heat, and in ſuch caſes an evaporating veſſel ſet in any iron pan full of water over a fire, will often anſwer every purpoſe, care being taken to ſupply water as it evaporates.

A greater heat is given by the *Sand-Bath* (Pl. I. Fig. 10—VIII. 82—X. & XI. Fig.

K. L.) which confifts of an iron pot funk into a furnace, and filled with fand. It takes a longer time to heat than the water does, and the heat is much lefs uniform through the fand, being confiderably greater at the bottom of the fand than at the top. The utmoft heat ufually given to the fand-bath is that of low rednefs, and it has the advantage of keeping very hot for a long time, without any additional fuel.

In a few inftances ftrong brine, or mercury, are ufed as balnea. The former when boiling is confiderably hotter than fimple water, fo that water immerfed in boiling brine may be brought fully to the boiling point. Mercury will receive a much greater heat, and it perhaps might be more frequently ufed with advantage than it is at prefent, for heat penetrates through it with much more rapidity than through water, and every veffel ufed in chemiftry with their materials, will float upon its furface. The mercury fhould be in an iron pan, and fhould be kept much below its boiling or evaporating point.

The terms water and mercury bath are often ufed, though not quite correctly, for the PNEUMATIC TROUGHS of thefe fluids ufed in operations on gaffes (which fee).

BELL GLASS. BELL RECEIVER. Pl. I. Fig. 17.—IV. 52.

This is a very ufeful form to be given to large glafs veffels in a variety of experiments on gaffes, particularly where any vacuum is produced, as the vaulted form of the veffel refifts the great force of atmofpherical preffure. It is therefore employed in experiments with the air-pump.

BLAST FURNACE. See FURNACE.

BLOW-PIPE. Pl. VII.

When a fmall jet of air is directed laterally into the middle of the flame of a lamp or candle, a portion of the flame is diverted in the direction of the jet, and forms a long flender cone of flame, the heat of which increafes towards the end of the cone, and at the very point its intenfity is extreme. This affords a moft convenient way of heating in a very high degree with a moft cheap and fimple apparatus, and almoft inftantaneoufly, any fubftance minute enough to be involved by the flame, and of performing a vaft number of experiments by which the nature of fubftances may be difcovered, though the actual quantities employed are generally too minute to enable the chemift to afcertain relative proportions with accuracy.

The inftrument by which the jet of air is produced, is called the blow-pipe, of which there are feveral kinds. The moft common is that ufed by the mouth, and need not be more than a tube of brafs or any other material, bent near the end the furtheft from the mouth, and drawn out fufficiently fine to keep up a conftant rapid ftream of air by the fupply that the mouth is able to furnifh.

But as in the courfe of blowing, the moifture of the breath is apt to condenfe in a troublefome quantity, an improvement has been adopted of making a bulb near the fmall end of the pipe, which, to render it more portable, is divided through the middle, and the two parts fcrew together when ufed. Fig. 73 *a b* is a common brafs blow-pipe of this kind, and inftead of the pipe itfelf terminating in a fufficiently fmall opening, a feparate jet-pipe (Fig. 72) is flipped on, of which there are two or three different fizes in the bore, according as a larger and more moderate, or a fmaller and more intenfe flame is required.

Fig. 71 is a blow-pipe of the fame kind, but ftill more convenient. It contains, like the former, a circular enlargement to condenfe the moifture, but the fmaller end *d* is moveable in any direction round the center *c*, whereby any degree of obliquity may be more conveniently given to the flame. The jet pipe, Fig. 72 is ufed as in the laft, and an ivory mouth piece, *b*, flips on the larger end, being pleafanter to the lips.

The beft kind of flame for blowing through with the common blow-pipe is a wax or tallow candle with a very large wick, which fhould be kept fnuffed moderately low, and the wick turned a little afide from the pipe. A fpirit lamp is fometimes ufed, which makes a perfectly clear flame without fmoke, but weak when ufed in this way. There is a kind of knack in blowing with the mouth, which is not eafily defcribed, and requires a little practice to be performed with eafe. As the flame muft often be kept up for feveral minutes, the act of refpiration muft be carried on through the noftrils without interruption, and the ftrefs of blowing muft be performed merely by compreffion of the cheeks upon the air in the mouth.

The fubftance to be heated is placed either on a piece of charcoal or a metallic fupport. When the former is ufed, a large clofe well-burnt piece of charcoal muft be chofen, a fmall fhallow hole fcooped out with a knife, and the fubftance laid upon it. The charcoal itfelf kindles all round the hole, and the hole is thus gradually enlarged; and the heat too is kept up round the fubftance much more uniformly than when a metal fupport is ufed. At the fame time however the chemical effect produced

by heated charcoal ſhould not be forgotten, particularly the reduction of metallic oxyds, and the deoxygenation of the fixed acids; ſo that, for example, a ſmall heap of minium or litharge heated red-hot on charcoal by the blow-pipe, is ſpeedily reduced to a globule of metallic lead; the phoſphats are partially reduced to phoſphurets, &c.

For a metallic ſupport, platina is in general by far the beſt material. A ſmall ſpoon of this metal is repreſented of the real ſize in Fig. 74; the ſhank of which may be ſtuck in a cork when held. Fig. 70 is a ſmall ſilver cup, alſo of the real ſize, the ſhank of which is fixed into a wooden handle. Fuſions with borax or alkaline fluxes may be performed in them. Fig. 75 is a ſmall forceps lately brought into uſe, and made entirely of two thin pieces of platina joined by rivets and bent in the manner repreſented. Any ſmall hard ſubſtance may be held by them in the blow-pipe flame for any length of time without danger of the points of the forceps melting, and it is alſo found that this metal is ſo much worſe a conductor of heat than any other, that the forceps never get too hot for the naked fingers to touch at the bend.

In the common way of uſing the blow-pipe there is this inconvenience, that one hand of the operator is employed in holding the pipe, and the other, the ſupport; ſo that he cannot turn, or in any way manage the ſubſtance heated, nor trim the lamp without ſtopping the proceſs. Several contrivances have been employed for ſupporting one or the other, and giving the operator the free uſe of one or both his hands, ſome of which are complicated enough, eſpecially where a candle is uſed, as in this the height of the flame is always altering as it burns away. The little apparatus, Fig. 76, is perhaps as convenient as any, where a lamp is uſed. The kind of lamp here repreſented is of the ſhape of a ſlipper, and when employed by the glaſsblowers, the wick is a large ſkein of cotton, and the blaſt is made by double bellows that are fixed beneath the table and worked by the foot of the artiſt, who ſits before the lamp, and thus has both his hands and mouth at liberty. The ſmoke given out by this kind of lamp is ſo much that it is neceſſary to have a ſmall iron chimney with a flue hanging juſt above it. (See the article *Glaſs*, Vol. I. p. 503.)

Another method of keeping up a continued ſtream of air without either the mouth or bellows is to fix a blow-pipe tube to the air tube of a gazometer, Pl. V. Fig. 61 & 2. *e* filled with common air, and the ſtrength of the jet may be increaſed by leſſening the counterpoiſing weights. (See the article *Gazometer*.) The ſame apparatus alſo affords an opportunity of giving in a ſmall ſpace the higheſt poſſible heat that combuſtion can procure, by ſubſtituting oxygen gas to common air in the gazometer. Hence it is of advantage to have the jet pipes tipped with platina, for if they are of braſs, they are liable, without conſiderable care, to melt down by the intenſity of the heat produced, or if of iron, they might readily be burnt. Some of the effects of this intenſe heat on refractory bodies are related under the article *Oxygen*.

A very ingenious blow-pipe has been invented (we believe by Mr. Paul of Geneva, known by his excellent preparations of the artificial mineral waters) which conſiſts in paſſing the vapour of boiling alcohol through the flame of a lamp, whereby it is kindled, and produces a very large cone of clear blue flame, perfectly free from ſmoke, and of ſufficient intenſity to melt ſmall quantities of glaſs for barometers and thermometers, and for many other uſeful purpoſes. Every part of this apparatus is entirely independent of the artiſt, ſo that he has both his hands and mouth at full liberty.

A repreſentation of Mr. Paul's alcohol blowpipe with a few alterations is given in Pl. VII. Fig. 69. The whole is neatly turned in braſs, and conſiſts of the following parts.

a is a hollow oval frame about 5 inches in its longeſt dimenſion, which ſupports the pillar *d* and the two lamps *b c*, which may burn either oil or alcohol, but the latter is the beſt. The rim *e e* ſlips upon the pillar *d* as low as the ſhoulder of the latter will permit, but the rim may be raiſed at pleaſure and kept faſt by the ſcrew-peg *f*. The rim ſupports the boiler *g* which is a ſingle hollow piece of thick braſs which will hold about an ounce of alcohol, and has four openings, viz. three at top *h*, *i k* and one at bottom to receive the tube *o*. This latter is long enough to reach to the level of the outſide of the top of the boiler, and conſequently the alcohol within the boiler cannot readily boil over into the tube, and the opening *k* which correſponds with it, is cloſely ſhut by a ſcrew ſtopper, hollowed out a little beneath, to allow the free paſſage of the vapour down the tube. Here the vaporized alcohol is prevented from condenſing at the point *o* by the contiguity of the flame of the lamp *b*, and as it paſſes on through the hollow *p q* into the jet tube *r*, it is immediately kindled by the flame of the lamp *c*, and the united flames are compelled ſideways with ſuch vio-

lence as to form a long pencil of blue flame, attended with a confiderable roaring noife. This continues as long as any alcohol is left in the boiler, which allows ample time for moft blow-pipe operations. The boiler is filled at the opening *h*. The centre hole *i* is nicely fitted with a fmall brafs plug kept down by a thin flip of iron *l*, the other end of which flips over the top of the upright pillar *d*, and is confined between two flat fcrew-plates *m n*. The ufe of this is as a fafety valve to take away all danger of the boiler burfting by the confined vapour not being able to efcape faft enough through the jet-pipe *r*, for when the internal preffure is great, the elafticity of the iron fpring *l* allows the valve *i* to rife fufficiently to let out part of the enclofed vapour. The fcrew ftoppers *h* and *k* are made ftill tighter by collars of leather, as is the part where the tube *o* joins the boiler. The jet-pipe *r* has a compleat rotatory motion, fo that the flame may be compelled in any direction. This is effected by turning in the form of a ball that part of the pipe which is enclofed in the hollow *p q*.

BURNING GLASS and MIRROR. See Solar Heat.

CALORIMETER. See the article *Caloric*, p. 216 in the former part of this Dictionary.

CAPITAL. A capital or head, is the upper part of an alembic, or other diftilling apparatus, in which the condenfation of the vapour begins. See Distilling *Apparatus*.

CARBOY is a very large glafs veffel of the form of a compreffed globe, with a fhort neck, ufed by the manufacturers for containing fulphuric acid. It is generally protected by a bafket of wicker work.

CRUCIBLE. Pl. I. Fig. 22 and 26.

A crucible is a pot generally made of clay, but fometimes of other materials, and intended to bear a ftrong heat. (For fome obfervations on the quality of thefe fire-veffels fee the article Pottery, in the former part of this work). The common fhape of the earthen ware crucibles, is either three-cornered or round, and they are fitted with ftoppers of the fame materials, (Fig. 23 and 27) perforated with a fmall hole, opening obliquely to allow the efcape of any volatile matter, and to prevent any of the fuel from dropping in. As the lower part of the crucible would efcape the greateft intenfity of heat, and would be liable to crack by the draught of air if it was fet directly upon the grate of the furnace, it is ufually raifed about two inches by a fmall ftand, which may be either folid Fig. 24, or hollow Fig. 25. The latter when inverted, alfo forms a convenient ftand for an earthen retort. The lid of the crucible may be luted on, when neceffary, with any kind of fire lute (as already defcribed in the article *Cement*, Vol. I.) particularly with the mixture of borax and clay. It is often of advantage to line the crucible with charcoal, for example, in the reduction of metallic ores that require no flux, fuch as the black oxyd of manganefe. Chemifts have ufually done this by fitting into the crucible a folid piece of clofe well-burnt charcoal, and fcooping out a hole in the latter; but it is a much more convenient way to mix fome powdered charcoal with a very little linfeed meal, to moiften it with juft fo much water as will bring the mixture to a ftiff pafte, and to line the crucible with it when wet. On applying heat, the linfeed meal burns, and gives out a little flame and fmoke which efcape through the hole of the cover, but this does not derange the charcoal lining.

Crucibles are alfo made of caft-iron, of fine filver and of platina. The former are fometimes of advantage in analyfes where a very ftrong heat is required to be given to fubftances in contact with alkaline fluxes, but they are feldom ufed. Silver crucibles are employed with great utility in the common analyfis or refolution of minerals by cauftic alkalies; and they are alfo extremely ferviceable in a variety of other experiments, where a heat not exceeding moderate rednefs is required, and where the fubftances do not act upon this metal.

The ufe of platina for crucibles has fo much increafed of late that it is confidered as effential to a well-furnifhed laboratory, and indeed not without reafon, as there is no fubftance that unites fo fully the qualities of infufibility at almoft any heat with refiftance to the action of almoft every chemical reagent. The cauftic alkalies however have fome diffolving power on this metal as is mentioned under the article *Platina*. Where a crucible of this metal is ufed for very high heats, particularly in fires fupplied by coal or coak, it fhould be loofely inclofed in a refractory earthen crucible, otherwife the vitreous flag of the coal is apt to encruft the outfide of the platina veffel, and adhere to it with fo much force that it can hardly be got off without great violence.

CUCURBIT. Pl. II. Fig. 39. *a*.

This is an oblong glafs veffel with a very wide mouth (nearly of the form of a long *gourd*, whence its name) ufed for various chemical purpofes, and in particular it forms the body of the common glafs alembic.

CUPEL. Pl. I. Fig. 28 and 29.

This is a solid paste of bone-ash moulded in a short cylindrical or truncated pyramidal form, with a shallow circular cavity at the top, about the size of a segment of a large bullet. It is used in the process of *Assaying*, (which article see in Vol 1. p. 110.) In making cupels the powdered bone-ash is moistened with a very little water, and the mass is made into the required form by being struck with considerable force into a mould of brass or iron, and afterwards gradually dried. By this means it acquires sufficient hardness for the use to which it is put.

DETONATING JAR. Pl. VI. Fig. 67.

It is frequently necessary in the analysis of some gasses to take the electric spark on given quantities in close vessels, such as mixtures of oxygen and hydrogen, which last forms the eudiometer contrived by Volta, and bears his name. It consists of a thick glass tube quite open at bottom, and near the top are two perforations in which small wires are cemented that approach each other within the jar near enough to communicate the electric spark, from an adjoining machine, whereby the inclosed gasses are fired. In most cases where this apparatus is used it is with mixtures of gasses that detonate strongly when fired, which is attended with some inconveniences. If the jar in which the experiment is fired is closely stopped a very small quantity of hydrogen and oxygen will burst pretty thick glass; and if it is entirely open, so that all the force of the explosion may be spent on the liquid in which the lower end is immersed, a good deal of it (especially if it be mercury) is thrown out and dispersed to a distance. These inconveniences are entirely remedied by the detonating jar described in the Plate (invented by Mr. Pepys) in which the jar is supported by the heavy iron stand *c*, which has a strong spring near the foot that draws out in the manner of the steel-yard when the concussion is given; and thus much larger quantities may be safely detonated than can be done by the common apparatus, without spilling any of the mercury. The shock is taken by wires that pass through the holes *a* and *b*.

DIGESTER.

A digester is a thick iron boiler furnished with a strong lid perfectly tight, that may be screwed down with force sufficient to resist the expansive force of the inclosed steam, whereby the water or other liquid which it contains may be heated considerably higher than the natural boiling point of water when unconfined. But as the strength of the vessel diminishes, and the force of expansion incre..es as the heat is raised, there is a point at which the vessel would burst, and a dangerous explosion would take place, if it were not prevented by a safety valve, with which all these vessels are furnished, and which will open and let part of the confined vapour escape when the expansion has reached a certain point. There are some cases where a digester proves an useful part of chemical apparatus, but it is not often employed.

DISTILLING APPARATUS.

Under this article we shall describe the different kinds of alembic, the common still, with its worm-tub, and the other apparatus for simple distillation, or that in which the sole object is to condense and collect in a liquid from the heated vapour of any substance. When a part of the product to be collected is either a permanently elastic gas, or a vapour which requires to be passed through water or any other liquid in order to be condensed, it is necessary to employ a more complicated apparatus similar to that which was originally invented by the late Mr. Woulfe, and will be described under the article Woulfe's Apparatus.

The simplest apparatus for distillation with moderate quantities is the Retort and Receiver. The former is made either plain (Pl. I. Fig. 5.) or tubulated and fitted with a ground stopper Fig. 2. It should be roomy at the bend, as it is there where the vapour first begins to condense. When the plain retort is used, the materials to be distilled, if liquid, should be poured in by a very long funnel, so that none of it may trickle down the neck. The bottom of the retort where the heat is applied is blown pretty thin, and being of uniform thickness it will always bear the heat of an Argand lamp, or even it may be slung upon a small chain over a common open coal fire when burning clearly, with very little risk of breaking, if tolerable caution be used. The neck of the retort passes into that of the receiver, or sometimes with the intervention of an *Adopter* (Fig. 3.) and the joinings should be luted. The receiver should be of considerable capacity compared to the retort, such as Fig. 4. to Fig. 2. to allow a large cool surface for the condensing vapour, and it may be further kept cool by covering it loosely with a cloth frequently wrung out of cold water. The receiver may be either a simple globe with a neck Fig. 6, or may be drawn out into a long tube at bottom, as in Fig. 4, in which case the tube should enter a bottle placed beneath.

When the receiver is tubulated it gives the advantage of allowing all the joinings between it and the retort to be perfectly air-tight, without danger of the vessels bursting by the expansion.

The alembic employed for distillations in larger quantities than with the common sized retorts is represented in Pl. II. Fig 33 and 34; the latter of which is a section of the former. This is taken from a drawing of a very excellent alembic made of tinned copper, almost exactly the same as that given by Beaumé in his Elements de Pharmacie, and used by that excellent practical chemist. It contains besides the essential parts of the apparatus the very useful addition of a water bath, which may be employed or taken out at pleasure. This apparatus consists of the four following pieces: *a a* Fig. 33 and 34 is the boiler, which is let in to a portable furnace to the height of the shoulder. It has a small opening at the upper part, stopped with a cork, by which fresh liquor to be distilled may be poured in during the process of distillation without deranging the apparatus: *b b* is the water bath which sinks almost to the bottom of *a*, and is therefore kept entirely surrounded with boiling water. *c* is the capital or part in which the condensation of the vapour begins. It is only seen in Fig. 34, being hid in Fig. 35 by the vessel *d*. The capital is of a conical shape, and at the lower part of the cone a small gutter is made by a doubling of the copper plate, which terminates in a conducting pipe that points obliquely downwards. The capital *c* is entirely inclosed and cemented into the refrigeratory *d*, so as to make but one piece with it. The use of the vessel *d* is to contain cold water, which by cooling the outside of the capital *c* facilitates the condensation of the vapour within it and causes it to flow in a stream down the conducting pipe. *e* is a cock belonging merely to the refrigeratory *d*, to let the water off when too much heated by the boiling vapour in the capital. The vessel *d* has also two handles, by which it may be lifted on and off more conveniently. This apparatus is so constructed that the water bath *b* may be entirely removed, in which case the capital with its refrigeratory closes directly upon the boiler *a*, which then contains the matter to be distilled. A capital and refrigeratory fitting upon a small boiler is also shewn in Fig. 35. This is often made of block tin, and is very useful in distilling water for chemical purposes with little trouble.

There is however one disadvantage in the alembic with the refrigeratory thus placed on the top of the apparatus, which is, either that the water of the refrigeratory soon gets so warm as not to be able effectually to condense all the vapour; or if it is kept constantly cold, a considerable part of the condensed vapour drops back again into the boiler, which is directly beneath it, and thus the process is prolonged, besides the danger of altering the quality of the product by the long heating. To remedy this defect several chemists (and among them Beaumé) have added to the alembic a serpentine or worm tub (such as is represented in Fig. 32,) into which the conducting pipe of the capital opens, and it is this addition probably which has led to a great simplification of the apparatus, by removing entirely the refrigeratory round the capital and causing the whole of the condensation to be performed in the serpentine. This forms the common still with its adjoining worm-tub, which is now used with some variety of construction almost exclusively in this country both in the large way in the vast manufacture of distilled spirits, and where only a few pints of distilled liquor are wanted, and which has, with us at least, almost entirely superseded the old alembic.

The common still, Fig. 31, consists of only two parts, viz. *a* the boiler, which is here shewn as partly buried in a portable furnace; and *b* the head or capital, which consists of a pretty large hollow globe, the upper part of which is drawn out into a curved pipe that makes a compleat arch and terminates at *c* Fig. 32, where it enters the upper part of the serpentine, or worm. This latter is a long pipe made of pewter, with a decreasing diameter to the bottom, and fixed in a tub filled with cold water, which effectually condenses the vapour, so that the liquid falls in a thin regular stream from the lower end of the serpentine. The joining between the boiler and head of the still generally requires a slight luting, for which slips of paper dipped in paste, or of wet bladder neatly applied over the circle of junction is sufficient. The line of tube from the bend of the still-head to the very bottom of the worm-pipe should be a gradual uniform slope downwards, and some nicety is required in the maker to give the serpentine that regular falling spiral line which is found the most favourable to speedy condensation. The chief disadvantage of the spiral worm-pipe is the difficulty of cleaning it and getting out the remains of any strong-smelling substance, such as an essential oil; whereas the large alembic capital is easily cleansed.

For distillation of small quantities of easily condensible substances, where much nicety and cleanliness is required, the glass alembic, Fig. 39, is highly useful. It consists of two pieces, viz. *a* the cucurbit or boiler, the bottom of which is made thin so as to bear a lamp-heat, and *b* the capital. These are sometimes made tight by luting and sometimes by grinding. The beak of the capital may pass into the glass balloon *c* or into any other convenient vessel, which last may also be surrounded with cold water or ice, if required. The glass alembic is in some respects better than the retort and receiver, inasmuch as the vessel to which heat is applied can be got at much more easily to be filled or cleansed, but it is an expensive apparatus and liable to accidents.

The old vessel called the Pelican Fig. 38, is a kind of alembic so contrived as to allow the distilled liquid to fall down again perpetually into the vessel whence it was expelled. An improvement on it, Fig. 37, is of the same kind. See Pelican.

DOME is the upper part of several kinds of furnace, round which the flame of the fuel reverberates before it enters the chimney. See Furnace.

EUDIOMETER.

The various processes belonging to *Eudiometry* or the ascertaining the purity of the air have been mentioned under that article in the former part of this work. Some of the most convenient vessels for that purpose may be here described.

Pl. I. Fig. 18. is a graduated jar for measuring gasses. It is made wider at bottom to stand more steadily. There are two ways of graduating jars, either of which any one may readily perform for himself. Select a very small phial or tube which will exactly hold, when brimfull, an aliquot portion of a cubic inch, which is determined by weighing the contents, allowing for the cubic inch at 60° temperature $252\frac{1}{2}$ grs. of distilled water. Fill the eudiometer jar with water at 60° invert the empty phial under it, and turn it up when within the jar, by which means the required portion of a cubic inch of air will rise to the top of the jar. Paste a long slip of paper round the level of the water in the jar, and then repeat the same operation till the whole is graduated. The lines may then be marked with a diamond, or a fine three-cornered file, and numbered, and the paper scraped off.

In graduating a jar in this method there is a little trouble in getting a phial to hold the precise quantity, and it will be more accurate if the rim round the neck is taken off and the edges ground smooth. If the required weight of water does not quite fill it, a small pellet of wax or cement may be added, and this may afterwards be melted upon the bottom of the phial to diminish its capacity. In graduating a jar in this manner, the hand of the operator should touch the phial only for an instant, and at the thickest part of the glass, to avoid the expansion of the contained air by the warmth of the hand.

Another method of graduating is to weigh in the jar itself successive portions of distilled water corresponding with the divisions of the cubic inch intended to be marked, and to scratch the levels by the file or a diamond. This is in some respects more accurate than the former, as, with tolerable care, it obviates all danger of any sensible error from accidental changes in temperature, the whole measurement being made with water in which the difference of a degree or two is scarcely felt. There is only this circumstance to be observed, which is, to carry the lines of division nearly round the whole circumference of the jar, otherwise some deception may easily arise in the use of it, unless the surfaces of the top and bottom of the jar are exactly parallel to each other; for when graduated by successive quantities of water, it is obvious that the jar must stand on its closed end, and the contrary when graduated by portions of air.

The above instrument is simply a graduated jar, and therefore somewhat improperly called an *eudiometer* jar, but two or three direct eudiometrical vessels have been contrived whereby the substance intended to analyze the contained air by absorbing a portion may be conveniently applied to it.

Dr. Hope's eudiometer is the following: Pl. IV. Fig. 55.

It consists of two parts, the lower of which is a short thick bottle with an upper and a side opening (the latter closed by a glass stopper) and the upper part is a graduated tube closed at top and accurately fitting into the lower bottle by grinding. To use it, take off the tube and fill it quite full with the gas to be examined, and also fill the bottle with the eudiometrical liquid (sulphuret of lime for example) and without shaking it, sink it in water. Then, immersing the open end of the tube in the same vessel, bring it over the bottle and thrust it in. The bottle and tube may then be taken out, and well shaken, that the liquor may thoroughly

come in contact with the contained gas, and the bottle from time to time immersed again under water, and the side stopper a little loosened that the water may rush in to supply the partial vacuum produced by the absorption. This will indeed somewhat dilute the eudiometrical liquor, but not so as to prevent it from acting. When no more absorption takes place the process is finished, (which only requires a few minutes at longest) and the absorption is noted at once by the graduated scale; or if the tube is not graduated, the residual gas may be transferred to another that is.

Another eudiometer which is intended merely for the analysis of the atmospheric air of any situation, is that of Mr. Davy, Pl. IV. Fig. 56. which consists simply of a portion of glass barometer tube, bent into two legs of equal length, both of which are furnished with glass stoppers, and one of them graduated. It is used in the following way. The tube is of course filled with the air of the place which it occupies, or for greater certainty, it may be first entirely filled with water, and then inverted, by which the adjoining air will come in as the water falls out. Then holding it with the bend lowermost, and both the stoppers out, drop down through the plain or ungraduated side a little water, till it reaches the beginning of the graduation, and close the graduated side with the stopper, so that the air occupies exactly the whole of the graduated space. Then pour down the plain side upon the water the eudiometrical liquor (sulphat of iron holding nitrous gas in solution) till this side is quite full, and close this stopper also. The whole cavity will then contain a known portion of air in contact with the proper liquor, which by agitation will absorb all the oxygen of the air in a few seconds, and by loosening the stopper of the plain side under water, the residuary gas on the other side will shrink to its proper volume, and may immediately be estimated.

Volta's eudiometer for the detonation of the inclosed air, with measured portions of hydrogen, has been already mentioned under the article *Detonating Jar*.

EVAPORATING VESSEL.

Evaporation is one of the commonest operations in chemistry, and in the small way may be performed with sufficient ease in almost any open vessel. The evaporating vessels made for this express purpose are sometimes of metal, but generally either of glass or earthenware. The glass vessels used in this country are segments of spheres blown thin enough to bear a lamp heat, and sold in assortments of different sizes, from the capacity of nearly a pint to that of about an ounce. A broken matrass or Florence flask, cut round, will answer the purpose extremely well. The globular shape of all these vessels however renders them difficult to heat, but it is difficult to get glass much flatter at bottom and retaining that uniform thinness which is necessary to make it bear the application of heat.

Very convenient evaporating vessels nearly flat-bottomed, are made by Messrs. Wedgwoods, and sold in nests or assortments, the largest of which will hold 8 or 10 pints. They are sometimes plain, sometimes with a lip in the upper edge, that the liquor they contain may pour better. The shape of a plain evaporating vessel is seen in Pl. I. Fig. 9. They are made either with or without glazing. Even when unglazed they hold any liquor without soon imbibing it, as the texture is a very dense, hard, biscuit porcelain; though in great length of time saline solutions will make their way through, and shew themselves in efflorescences on the outside.

These evaporating vessels will bear to be heated to boiling, over a clear hot fire, such as that of charcoal or cinders, but they are liable to crack when exposed to jets of flame, or unless heated with some caution at first. No liquor should be boiled to dryness in these vessels, as they generally crack whilst the last portion of fluid is expelled unless the heat is much lowered.

FILTER. Filtration.

Filtration is constantly required in chemical processes, in order to separate fluids from substances suspended in them. In most instances it is performed by throwing the whole upon a conical bag made of any porous materials, such as flannel, linen, or paper, which detains the solid part, and allows the fluid to pass through clear. Where the quantity of materials is large, and the solid is of a nature to be not easily suspended in water, a flannel or linen bag is preferable, as it is much more expeditious than paper. Thus for example, where in the first step of making phosphorus, bone-ash is decomposed by sulphuric acid, and the whole diluted with much water, the liquor is obtained very clear by throwing the whole on a conical linen bag; and though the first few ounces may be turbid, the runnings soon become perfectly limpid. Where the object is, as in this case, to preserve the liquor that runs through, linen is preferable to flannel, as the latter soaks up a larger quantity of liquor, which must be got out by subsequent washing

and wringing. But where the solid residue is the only valuable part (as in filtering the citrat of lime formed by chalk and lemon juice) flannel answers as well and is more speedy. In small quantities, and where accuracy is required, the material of the filter is generally a square thin unsized paper, first doubled from corner to corner into a triangle, and the latter again doubled into half the size, making another triangle. This when opened forms a paper cone, into which the liquor is poured, and which must be supported by being put into a glass funnel. There is always some little loss of materials incurred by filtration, particularly of the fluid which passes through, for the paper must of course absorb a quantity of it, and though after the first filtration, the filter is repeatedly filled with warm water, it is impossible to wash out every particle of the saline solution with which it was at first impregnated. This is one reason why in all analyses of minerals in the moist way, the sum of products obtained by the most accurate experiments always falls short a little of the original weight of the mineral employed; so that if they should prove exactly equal, there is reason to suspect some little error in the computation, or a want of desiccation in the products equal to that of the substance used.

To collect at the bottom of the filter every particle of the residue, it is very useful to have a small glass tube open at both ends, and drawn out into a very fine capillary point at one of them. When this is filled with distilled water and the larger end put into the mouth, the force of the breath can direct a small strong stream of water round the sides of the paper funnel, which will wash down to the bottom every minute particle of solid substance. When the filtration is finished and the residue properly edulcorated, it must be dried in part before it can be taken clean off the paper. Sometimes the quantity of residue is so minute, and sticks so much to the paper, that it cannot be scraped off when dry, at least not with sufficient accuracy; as, for example, where the quantity of sulphuretted hydrogen of a mineral water is to be estimated by precipitating and weighing the sulphur. In such case the most accurate way is to filter as usual, but instead of attempting to remove the residue, to weigh it against another piece of filtering paper previously cut exactly of the same size as the filter, wetted, and dried at the same temperature, and the difference in the weights will indicate the quantity required.

The substances that cannot be filtered in the common way, are those which act too powerfully upon the paper and other materials employed. The concentrated acids and alkaline solutions are of this kind. Where it is required to filter them, which is not often the case, they may be poured through a stratum of coarsely powdered glass, or well washed white sand, in a glass funnel. See Funnel.

A convenient stand for filtration with a drawer at bottom to hold filtering paper, &c. is shewn in Pl. VI. Fig. 65.

FLASK.

This hardly differs from the *Matrass*.

The flasks of green glass ingeniously covered with rushes, in which the finest oil is imported from Italy, form very useful chemical vessels and at a low price. They are extremely thin, and will bear heat very well, and being made of a hard glass without litharge, they will bear a low red heat without materially softening or losing their shape. On this account too they are the best vessels for performing sublimation in, with small quantities of materials, and if necessary they may be coated for this purpose by diffusing clay in water to the consistence of thick cream, and dipping the flask in up to the neck, repeating the operation successively as soon as each coating dries.

The flasks must first be cleaned by a little sand, and any refuse solution of alkali, somewhat caustic, boiled in it, and shaken about till all the oil within is dissolved. Very useful cup-shaped vessels for evaporation and other purposes, may be made by cutting off one of these flasks round the bottom of the neck or the middle. This is done with ease in the following way: if the flask is sound, heat a piece of the thickest iron wire fully red-hot, and lay it on the part you wish to divide, moving it backwards and forwards slowly in the intended direction of the crack. This will generally succeed in beginning the crack, after which it may be led along with extreme ease, simply by bearing gently with the hot iron in the course which the crack is to pursue, till the division is compleat. But among a number of flasks there are generally some that have a little crack or flaw in them, and this may be led over any part of the vessel by the same means, and will cut it to the required shape. It should be remembered however, that though it requires a very hot iron to split a sound flask, yet when the least crack is made, it may be led along by a much less heat, and the cooler the iron is, the less likely the crack is to deviate from the intended direction. If the flask is split in the contrary direction, that is, perpendicularly through both the

neck and body, it forms two similar glasses extremely convenient for many small operations, and in which the split part of the neck serves both as a spout and handle. The greatest inconvenience attending these vessels made out of flask, is their excessive thinness at the middle, so that they are liable to split by the least blow, and when full of liquor they can hardly be taken up without danger of being broken by the pressure of the hand.

FORGE. See FURNACE.

FUEL. See FURNACE.

FUNNEL. The common funnel needs no description. It may be made either of glass or pewter, or tinned iron, or earthen-ware.

The *ribbed funnel*, Pl. I. Fig. 7. is better for supporting large paper filters than the plain ones; for in the latter case, the wet paper adheres so closely to the smooth glass as most materially to prevent the passage of the liquor through; whereas the ribbed funnels afford as many channels through the whole length of the paper, by which the fluid is drawn down to the bottom. A plain funnel may be made equal or superior to the ribbed, by arranging in a perpendicular direction at equal distances, a number of straws, or pieces of thin glass rod, to form an uneven surface, over which the paper filter is to be laid, and thus to prevent its adhering to the side.

It is useful to have in a laboratory a small glass funnel with a very long narrow neck, able to pass down the whole neck of a retort, by which liquors may be poured in, without any part of them wetting the neck of the retort.

FUNNEL SEPARATORY. The separatory funnel, Pl. II. Fig. 40. is intended for the separation of liquids of different specific gravity (as oil and water) by allowing the heaviest only to drop out of the bottom of the vessel. The funnel is first stopped at the bottom and then filled with the mixed liquors. When they have stood at rest till the heaviest has entirely subsided into the narrow part below, the cork at bottom is taken out, and when the stopper above is a little loosened the heavier liquor flows out. This vessel is used particularly in separating essential oils from the water which is necessarily entangled with them when collected from the water distilled from the plants that yield them. Some of these are lighter than water, others heavier, and they are both separated with equal ease.

FURNACE.

As heat is one of the great agents in chemical processes, the construction of the apparatus through and in which heat is applied must be of the first consequence, and accordingly a vast quantity of pains and ingenuity has been bestowed on the subject of furnaces. To describe every one that has been invented for general or particular purposes would far exceed our limits, we shall therefore only mention some of those which are the most commonly employed in the laboratory. The furnaces required for working ores and metals in the large way, for making lime, bricks, pottery, glass, &c. are foreign from our present subject, and most of them have been noticed under these respective articles as fully as is consistent with our general plan.

The furnace which is the most familiar to us is the *Common Grate*. This is an iron furnace of various shape cut down in front and the fuel kept in only by bars, in order to throw the heat out into the room. The utmost heat of a common parlour stove supplied with coals is barely sufficient to melt thin plate silver, for a piece of silver money will not readily melt in it unless it burns very strongly. But a very large number of the operations in chemistry are performed in a temperature not exceeding full redness, and for many of these the common grate is amply sufficient. The flat iron sides or cheeks will also furnish an inferior heat, on which evaporating and digesting vessels may be set. The common grate however has two disadvantages, one, that the openness of the front causes the escape of a great part of the heat, and incommodes the chemist in approaching it, and the other that coal is a very unsteady variable fuel giving much blaze and smoke, and requiring frequent stirring.

Before we describe the proper chemical furnaces, we may shortly state what must be their object and construction.

The simplest air-furnace that we can conceive is a cylindrical or conical earthen pot, open at top and with a grate fixed within a few inches from the bottom, and a pretty large opening just beneath it, in order to allow of the draught of air through the fuel and for the ashes to be cleared out. This draught-hole beneath the grate, of whatever form it be, is always called the *ash-hole* or *ash-pit*. If furnished with a stopper, the draught of air and consequent intensity of the fire may be regulated. The fuel is thrown in and the crucibles to be heated are introduced down the large opening at top. A cylindrical earthen pot thus constructed has already several advantages over the common grate of the same capacity; for the sides being entirely closed, the

whole of the air paſſes in beneath the grate and goes out above the fuel, whence the draught is proportionally ſtronger and the heat more intenſe, and it alſo may be approached without trouble. If a furnace of this kind is ſupplied with charcoal (which gives a much ſtronger heat than coal with a moderate draught of air) and the height above the grate is about double the diameter, a heat fully equal to the fuſion of a ſmall bulk of copper will be produced.

Still this is far ſhort of the temperature required for many operations, and therefore, (where the natural draught of air is reſorted to) it is neceſſary to increaſe this by incloſing the top of the cylinder with a dôme of the ſame materials, which may be further elongated by a chimney of any height. The draught of air is now prodigiouſly increaſed, and if the ſides of the furnace are pretty thick, and the chimney broad enough and high enough, an intenſity of heat is produced, able to melt iron, reduce manganeſe, &c. in ſhort, to perform nearly all that artificial fire can do. It is by no means neceſſary that the chimney ſhould be perpendicular in every part, and it is often much more convenient that it ſhould quit the furnace in an horizontal or oblique direction, as it allows a much readier acceſs to the furnace and its contents.

The proportion which the diameter of the chimney ſhould bear to that of the furnace, to give the greateſt intenſity of heat, has been variouſly ſtated, and it ſtill ſeems not to be well determined. From ſome experiments of Darcet and Lavoiſier it would appear that the greateſt poſſible heat obtainable by air furnaces, is procured by making both furnace and chimney one very long upright channel or flue, perfectly open at bottom and at top, the furnace itſelf (or the part of the channel juſt above the grate) being bulged out in a moderate degree to give greater room for the fuel and the fire veſſels. In general however the flue of the chimney is made a little narrower than the aſh-pit. A cloſe furnace of this kind intended ſimply for heating any veſſel in the midſt of the fuel, requires eſſentially no more than three openings, namely, the aſh-hole, the chimney, and a ſide-door, through which to throw down fuel, and to introduce and take out the ſubſtance to be heated.

Where diſtillation by naked fire is wanted, a ſmall addition is required, and a hole muſt be cut level with the middle of the retort, through which its beak may emerge, and connect with the receiver or other veſſel intended to collect the product. The retort in this caſe is generally earthen.

Another object in furnaces is to apply a moderate degree of heat to larger veſſels, which therefore can only be partially in contact with the fire. Moſt of the furnaces uſed in manufactures and for many common purpoſes are of this kind, ſuch as the common houſehold coppers for heating water, brewing coppers, ſalt-pans, &c. &c. Sand pots are alſo of this kind, and in all theſe, the ſubſtance to be heated is placed over the fire, ſometimes dipping into it. This alſo eſſentially requires only three openings, viz. the aſh-pit, chimney, and door for fuel, the ſurface of the ſubſtance heated being external to the fire.

Another purpoſe in furnaces is to incloſe and heat on all ſides an earthen oven or muffle, the mouth of which at the ſame time comes in contact with one of the inner ſides of the furnace, and is freely acceſſible from without by a correſponding hole cut through the ſubſtance of the furnace. This therefore requires another opening beſides the three former already mentioned.

It is ſometimes required in experiments of reſearch to place an earthen or iron tube in ſuch a manner that the middle of it ſhall be ſtrongly heated whilſt each end is cool, and projecting beyond the furnace, ſo that no part of the contents of the tube can come in contact with the fuel. This is done in a cloſe furnace, by having two holes through the ſides directly oppoſite each other, through which the tube may be thruſt.

One more mode of diſtributing the heat of a furnace may be mentioned, which is, where the ſubſtance to be heated is neither incloſed in any veſſel, nor in actual contact with the fuel, but is ſpread on a kind of floor immediately beyond the fire in a ſpace between the fire-place and the chimney, and receives the heat from the flame which draws over it. This forms the reverberatory furnace, and requires a very peculiar conſtruction, as will be afterwards explained.

The above are the principal objects to be fulfilled in the conſtruction of chemical furnaces for general purpoſes, but another great diſtinction is in the mode of ſupplying air, which may be either by the natural draught of air, or by bellows or other artificial means. In the former caſe the rapidity of the current of air and conſequent intenſity of the fire, depends on having a ſufficient ſpace in the aſh-pit and chimney, and eſpecially a very great length of flue, and all the ſide-openings which would break the current, carefully cloſed. But with an artificial

blaſt the ſtrength of fire depends ſolely on the degree of mechanical power employed in impelling the blaſt, and the chimney is altogether ſuperfluous except to carry off the ſmoke. Theſe kind of furnaces therefore are much ſimpler than the draught furnaces, as no more is required than a ſimple hearth or a ſhallow pot, with a ſmall hole at the bottom to conduct the air from the bellows. Large quantities of materials, as in the ſmelting of iron, can hardly be heated to the utmoſt intenſity without the artificial blaſt, and the aſſiſtance of a ſteam engine or ſome other very ſtrong mechanical force is neceſſary to keep up the conſtant ſupply of air. At leaſt, much time and fuel are ſaved by the blaſt, for if the heat of the moſt powerful draught-furnaces, ſuch as the porcelain kilns, may be brought to equal that of the iron-ſmelting furnace, it requires, however, a very large body of fuel and a great many hours to bring it to the utmoſt intenſity. But in the ſmall way, for experimental purpoſes, the higheſt temperature of a draught-furnace, when well built and properly attended to, appears to be no way inferior to the beſt blaſt, to judge by the comparative effects; and the greater conſumption of fuel and time is often fully counterbalanced by the ſaving of manual labour.

Some chemiſts have ſuppoſed that the heat of a furnace might be reflected from the ſides, and concentrated into one focus, by giving it a circular or elliptical form. This however is found by experience to be perfectly nugatory, for no ſenſible difference is obſerved between a cylindrical, globular, or elliptical fire-place, provided the dimenſions of the chimney and aſh-pit are the ſame. There is however a method of concentrating the heat of a blaſt-furnace, by dividing the blaſt into a number of ſmaller jets of air, and mechanically driving them towards a common center, as will be explained hereafter.

The materials of which furnaces are conſtructed is always a refractory clay, either in form of bricks, or, where the pieces of the furnace are ſmall, of entire pottery. The larger kinds of black-lead crucibles make extremely uſeful portable furnaces for a variety of purpoſes, being very infuſible, bearing pretty ſudden heating without ſplitting, and having the additional advantage of being ſo ſoft as to be readily drilled by a gimblet, and cut by a ſaw or hacked knife, whereby openings may be made and ſtoppers fitted without difficulty. Large moveable furnaces are often made of this kind of pottery, but much thicker than the common crucibles, and ſtrengthened on the outſide by iron hoops. A very uſeful white coarſe pottery is employed in France for portable furnaces, which bears the fire extremely well, but when baked is too hard to be cut like the black lead ware. Moveable furnaces are often made of a wrought-iron caſe lined on the inſide with ſmall fire-bricks, and the part immediately in contact with the fuel is further covered with a thick coating of Windſor loam, laid on when moiſt and plaſtic, and beat frequently with a wooden inſtrument when drying, to give it more compactneſs, and to fill up the ſmall cracks which the ſhrinkage occaſions. The fixed furnaces are always built of *fire-bricks* (a very hard infuſible brick, made for this expreſs purpoſe) cemented with a very refractory mortar; and the larger openings are either iron doors ſet upon hinges, or ſometimes a thick piece of free-ſtone, or very large brick properly faſhioned. There is a very ſoft red ſandy brick ſold in London, under the name of *Windſor brick*, which may be cut or ſcraped with great eaſe, and is extremely uſeful for ſtoppers, crucible ſtands, and many other ſmaller purpoſes, though it is too ſoft to bear any conſiderable preſſure.

A proper ſelection of the fuel is of firſt importance. Wood and charcoal were formerly the only materials employed for this purpoſe in this country, and are ſtill ſo in moſt other parts of the world; the firſt, where a large volume of flame is required, and the latter, for a ſtrong heat without flame. Thus glaſs-houſe and reverberatory furnaces were ſupplied entirely by dry faggots, and iron forges by charcoal.

Wood faggots give a ſtrong clear flame unmixed with ſulphur, and with but little ſmoke, and burn to a clean aſh, which alſo is valuable for the alkali it contains. From its freedom from ſulphur it muſt be in many inſtances better than coal, and it ſeems to have no other diſadvantage than the rapidity with which it burns out in a ſtrong draught, being ſo much more bulky than coal that only a comparatively ſmall quantity at a time can be thrown into a furnace. Hence in the large foreign glaſs-houſes that are fed by faggots, it is the work of one man to be inceſſantly adding fuel. But the ſcarcity of wood now forbids its uſe in moſt parts of this country, and the abundance of coal on the whole very well ſupplies its loſs.

Charcoal is a moſt valuable fuel for furnaces. It kindles readily, burns with a very ſtrong clear heat, and requires a much leſs draught of air for combuſtion than coak or charred coal; it contains no ſulphur nor any earthy or metallic

matter, and hence it never runs into a hard vitreous slag as coak does, but burns away into a clean light ash which falls through the bars of the grate, without choaking and hindering the draught of air, or melting down the clay walls of the furnace. The flues or chimnies also never collect any soot or foulness, and therefore never require cleaning. A much greater range of heat may be kept up by charcoal than by any other fuel, for its utmost intensity of heat fully equals that of coal or coak, and besides it affords the great advantage of burning away very slowly, with a gentle and pretty steady temperature, when the supply of air is just sufficient to keep the fire alive. Charcoal (besides being expensive) has however the inconvenience of being too light to bear a very strong blast of air in common blast-furnaces, except it is in larger pieces than is often convenient, and it also burns out very rapidly in a strong draught, so as to require a constant supply. There appears to be very little reason for preferring the charcoal of one wood over another, provided both are equally well burnt. It may be added that the wood intended for charcoal is always previously barked; when this is neglected the charred bark as soon as it is kindled burns with a short but prodigious eruption of sparks, often inconvenient to the operator.

Coal is the fuel almost invariably used in this country for common culinary purposes, for all manufacturing fires where a moderate heat is wanted, and the substance is not injured by the smoke, or can be put out of the reach of it (as in brewers and distillers coppers) and in the laboratory for heating sand-baths, for smith's forges, and also for the reverberatory furnace. It gives a large, strong, and very lasting flame, but for any intensity of fire it requires a pretty large and high chimney, and a wide ash-hole.

Coak gives a very strong heat without flame, and this is the general material for strong wind and blast furnaces, where an intense and durable heat is required. Coak, in the way it is commonly prepared, always gives out at first a blue sulphureous flame, which ceases when fully red-hot. On account of the great density of this substance it bears the blast extremely well, but being a much less pure combustible than charcoal, and containing a mixture of earths and oxyd of iron, it is very apt when nearly burnt out to cake together in an intense heat, and to run into a tough cohesive slag, quite glassy and sonorous when cold, and which melts on the surface of the crucibles, and can hardly be detached from them. Coak alone is not easily kindled, and requires a much more powerful draught of air than any other fuel, so that it cannot be burned in an open grate except it is in very large quantity. Its combustion is materially assisted, and its vitrification when nearly burnt out is much prevented, by mingling it with about its own bulk of charcoal, and these two together form the very best material for the furnaces that require an intense heat.

Coal cinders, picked from a common fire, by removing the coal just when it ceases to blaze, and before it begins to burn to ashes, is often preferable to coak for laboratory experiments, as it is of a much lighter and looser texture, and much less sulphureous, and burns more readily, giving out a very intense heat. The best Newcastle coal, of the kind that softens in the fire and is highly bituminous, gives the best cinder for this purpose, which, when cold, is glossy, light and sonorous.

A mixture of refuse coal and charcoal made up into irregular cakes and charred together has been introduced of late years for malt-houses and similar purposes where a strong clear heat is required, and this, when broken into small pieces, answers extremely well for the laboratory.

Culm or Welsh Coal (which has been described under the article *Coal*) differs from all the common kinds of coal in burning without any flame or smoke, or leaving much residue. In this respect it more resembles charcoal, and it has been found to answer very well as a fuel for small blast-fires; and being much heavier than charcoal, it is not so readily dispersed by the force of the stream of air.

Kilkenny Coal is nearly of the same nature as culm, but not so pure.

Turf should not be unnoticed, though it is seldom used. It is a useful material for lighting fires, and it burns for a long time with a low smothering heat, and much pungent smoke when the draught of air is very small. It might be employed for long digestions with a very gentle warmth, even more effectually than charcoal, and at very small expence, but these operations are now chiefly performed by the lamp, which is on the whole to be preferred.

* * * * *

We shall now describe some of the furnaces actually employed in the laboratory.

Pl. VIII. Fig. 77 and 78 are a view and section of *Dr. Black's Portable Furnace*, as it is called, being, with some variations and improvement, that which was invented by that eminent philosopher. It consists of an oval iron case

22 inches high, 20 in its largest diameter, and 15 in the shortest, lined with fire bricks for about three fourths of its height from the top, which forms the body of the furnace, and the first elbow of the chimney, whilst the lower part, which is not lined, forms a very spacious ash-pit. Being very heavy it is put upon castors, by which, with the assistance of the ring handles on the side, it may be moved along a floor without difficulty. *a, a*, is the body of the furnace, which is cylindrical, but a little oblique, that the flame of the fuel may heat the sand-bath somewhat more equally than if it were a straight cylinder. The breadth of this cylinder is 8¼ inches, and its height 15; the grate *c*, lies across the bottom. This fire place has the following six openings above the grate. The highest is the large opening at the top, which, when a sand-heat is employed, receives the sand-bath *i*, and Fig. 82, and when this is not wanted, is covered by a thick iron plate lined with clay, Fig. 80, in the center of which is a small hole fitted with a stopper, Fig. 81, through which the state of the fire may be seen without scorching the face. The next opening is the elbow of the chimney, *f*, which widens as soon as it takes a perpendicular direction, and for the first few inches forms a part of the iron case of the whole furnace, and is lined with clay, after which it is elongated by a conical iron chimney, Fig. 79. Even this small length of flue is sufficient to keep up a very considerable heat when the fire is well supplied with fuel, but to raise it to the intensity requisite for melting cast iron, it is necessary to add several feet of iron pipe of the same diameter as the top of Fig. 79. if it is set under an open brick chimney, or else (which is often more convenient) to close the throat of the brick chimney with an iron plate, leaving only a round hole in the middle, into which the upper part of the pipe, Fig. 79. closely fits. In this case no further length of iron flue is required to give a very strong draught through the furnace, capable of raising heat enough for almost any purpose of the chemist. Opposite the chimney hole in the body of the furnace, and a little below it, is the opening *e, e*, which serves to introduce fuel when the upper opening is engaged by the sand-bath, and the heat of the latter may also be lessened at pleasure by leaving this hole open, which causes a draught of cold air to rush in directly round the bottom of the sand-bath. The next openings are two small round holes, *g, g*, placed directly opposite each other at right angles with the perpendicular of the chimney, and serving to introduce an earthen or iron tube, the use of which will be explained under the article *Hydrogen* (*Apparatus for*). Below these is the sixth opening, *d, d*, cut of the proper shape to receive a muffle for which it is intended. The openings *e, d*, and *g*, are properly fitted with very thick stoppers, which are further covered with pieces of iron plate closely sliding in grooves, in the way represented in Fig. 77. The ash-pit is merely the lower part of the iron case that incloses the whole furnace, and is furnished with two doors, *b, b*, by which the draught of air may be regulated. The rings *b, b* (of which there are two corresponding ones on the other side) are intended to support upright pieces of thick iron wire, which, with a cross wire over the top of the furnace, will serve to suspend any vessel or other body over or in the furnace, as may be required.

A great variety of operations, and on a tolerably large scale, may be performed in this useful furnace, which is very durable, and being heavy and substantial, it is not liable to be damaged by accidental blows, or easily displaced; and it is besides extremely safe in a room, provided the chimney is clean. The iron case should be now and then rubbed with black lead to prevent its rusting. This arrangement of the chimney allows very free access to the body of the furnace, and the thickness of the walls prevents the operator from being at all molested by the intenseness of the heat. It is the least convenient for naked distillation from an earthen or iron retort, for though such a vessel might be set on a retort stand with its beak projecting through the opening *d*, neither the size nor shape of this opening are well adapted for this purpose, and to give a strong heat, a stopper of soft brick with a deep slanting groove must first be fitted in.

Fig. 83 and 84, of Pl. VIII. are a view and section of a *Muffle Furnace, for very intense heat*, employed by Pott, and afterwards by Darcet, in experiments on the habitudes of earths and stones in long continued and violent heat. The construction of this furnace is simple and obvious; *a, a*, is the body of the furnace, in form of an oblong coffer, bulging out in the middle. *c* is the grate standing over the ash-hole *f*; *e* is the hole for the muffle; *b, b*, is the dome or upper piece of the furnace, with a very large door *d*, through which the fuel is introduced. The draught is raised by a long perpendicular chimney, Fig. 85.

Pl. II. Fig. 41. is the lower part of a small *Portable Chamber Furnace*, often used in the

lecture room, and fitted for a great variety of purposes. The upper part (which is not here given) is a rounded dome terminated by a perpendicular iron flue.

It is introduced here merely to shew the experiment of procuring *hydrogen*, by passing steam through a heated iron tube, as will be further described.

The furnace itself is a neat iron case lined with fire-brick, and furnished with openings for a variety of purposes.

Pl. IX. Figs. 86, 87, 88, and 89, represent a view and section of a *Portable Blast Furnace*, of simple construction and little expence, which was suggested to the writer of this article from one of Dr. Lewis's, and described at large in the Philosophical Magazine, vol. xvii. *a* and *b* Fig. 86 and 87. are portions of two common black lead pots of the same diameter, the lowest of which is inverted, and stands upon a smooth stone, *i*, which is supported by an iron trivet about a foot from the ground. The pot, *a*, receives the blast of the double bellows as here represented, through the hole *h*. The upper part of this pot (or what would be the bottom when used as a crucible) being considerably thick, will allow of a small hollow to be scooped out of its substance, through which a wide hole must be drilled to the cavity below.* By this means the blast rises in a perpendicular direction and equally into the pot *b*, instead of spending itself chiefly on the side opposite to the bellows, which would be the case if the lower pot was not inverted. *b* is the pot which contains the fuel and the crucible or other matter to be heated. It is prepared in the following manner: drill a hole through the bottom with a gimlet as exactly in the center as possible, and enlarge it to about the size of a shilling. This hole is not for the passage of air, but to receive a crucible stand, *c*, and Fig. 89 in the form of a stopper, which keeps it steady. Then strike a circle with compasses on the smoothed bottom of the pot *b*, round the center hole, and bore through it upon the circle at equal distances, four or six large gimlet holes, in a slanting direction, so that if lengthened they would all meet nearly in the middle of the pot. No extreme nicety however is necessary in the precise direction of these holes, but the general intention of the oblique direction given them is to concentrate the force of the fire upon the center where the crucible *d* is placed. These two pots are all that is essential to the furnace, and when lighted charcoal or cinders are put in and the bellows worked, the blast rising from the lower pot divides itself equally through the four or six blast-holes in the bottom of the upper pot, and very speedily raises a very intense heat. No luting whatever is required here, the pots are simply ground smooth with water on any flat stone, and when used are merely placed in the manner here given. As they are only the lower parts of the large crucibles, the chemist may often find what will answer his purpose from the crucibles that are flawed or otherwise damaged. The stoppers are made very easily out of the soft Windsor brick. The bellows are fixed to a heavy stool, and their handle is lengthened to work easier, but of course any other form of double-blast bellows will answer as well. To protect the eyes from the dazzling heat which is produced in the pot *b*, it is often adviseable to cover it with the pot *e*, Fig. 88, which has a wooden handle *g*, fixed into it, and an opening for the flame and smoke *f*, which may be turned away from the operator.

The black-lead pots are the easiest cut by an old thin table knife deeply hacked or jagged.

Pl. IX. Fig. 90 and 91, is a plate and section of the *Reverberatory Furnace*, used for roasting and smelting ores both in the large way, and, on a smaller scale, for experimental purposes. In this furnace the substance to be heated is not in actual contact with the fuel, but is strewed on a separate floor or hearth, placed between the fuel and the chimney, and is heated by the flame in its passage through. The floor on which the ore is spread is called the laboratory, *d*, and is sometimes horizontal, but generally on an inclined plane, sloped from the fireplace to allow the metal when reduced and liquefied to collect and settle at the lower end. The floor of the laboratory is formed with sand mixed with a little clay, and well beaten into a smooth compact surface, and this is sometimes further coated with a mixture of charcoal powder and clay. The roof is vaulted, and low, so as to allow but a narrow space for the passage of the flame, but the precise curve to be given it is of little consequence, provided it is as flat as is consistent with due strength, in order to contract the space between it and the floor. The lowest part of the floor of the laboratory *e*, is called *the crucible*, and is generally left uncovered when the furnace is charged, as it is intended to receive the melted metal, which, when a sufficient quantity is collected, is drawn off from time to time through the channel *f*, which is kept plugged up with clay till the

* This scooped cavity is however by mistake represented much deeper than the real thickness of the pot would allow.

moment of casting. The grate of the fire-place *b*, is fixed a little lower than the level of the adjoining and upper part of the floor of the laboratory. The fuel is thrown in through a side-opening *a*, and is of a sort that produces much flame, such as wood or pit-coal, which therefore must traverse the whole length of the laboratory to reach the chimney *h*. The draught of outer air comes in through the ash-pit, and often is brought immediately from without, through the channel *i*. The chimney *h*, sometimes rises perpendicularly immediately above the crucible *e*, but at other times it leaves the laboratory by a side-opening, as here represented, which plan is particularly adopted in long ranges of reverberatories for smelting in the large way, where one lofty upright chimney serves for two furnaces, receiving a lateral flue on each side. The laboratory has besides two separate openings, one at *c*, which is in the same line with the door *a*, of the fire-place, and serves to introduce the ore; and the other at *g*, which looks along the whole length of the laboratory, and allows the introduction of a kind of iron rake, by which the scoriæ are drawn out. This opening has also a smaller sight hole in the center of the stopper, by which the progress of the work may be examined, or an iron bar may be thrust in to stir up the materials. The breadth of the laboratory at its upper part is the same as that of the fire-place, but it gradually contracts towards the lower end, that the heat may be concentrated upon the crucible where it is the most needed.

Plate X. is a perspective view of a very convenient and well contrived set of fixed furnaces lately built by Mr. Pepys, at his laboratory in London, whose liberality has allowed us to procure a very accurate drawing of the whole, reduced to the scale thereto added. Plate XI. contains two representations of the same; the shaded plan being a section on the level of the grates, and the outline plan, a perpendicular view of the furnaces. The letters of reference are the same for all. Plate XII. also contains certain detached parts which could not be represented in the general view.

This set of furnaces consists of the following, viz. a still with its worm tub—a forge hearth—a muffle furnace—a strong draught furnace for melting—a furnace for naked distillation—a square sand bath for digestions—and a round sand bath for distillation.

There is besides a small space left on the same level as the top of these furnaces on which a portable stove or black lead furnace may be set. The chimnies corresponding with these furnaces are five in number, placed side by side, and proceeding to the top of the building about 20 feet. The face of this stack of chimnies projects about a foot and a half into the room, and from it a screen projects, level with the cieling of the room, which hangs down in a sloping direction to about six feet from the floor. Its use is to collect and convey away all the smoke and fumes which would otherwise escape into the room. Each of these parts requires a fuller description.

A is the *Worm Tub* belonging to a ten-gallon *Still* B, which is of the usual form, and contains also a water-bath. The chimney, C, of the fire beneath the still is arched, and passes across the vacant space Q. into the first of the upright chimnies into which it opens.

E is the *Forge Hearth*. The blast pipe *a* of the bellows (which are moveable at pleasure) rises up into the hearth at *b* where the fuel is laid, as in the common smith's forge, and the smoke is carried off by the moveable iron pipe D, which passes up beneath the screen N (part of which is represented as broken away to shew the course of the pipe) and enters the first chimney. The hearth contains two small trenches at *d*, in which tongs and pincers may be conveniently set.

F is a *Muffle Furnace* of simple construction. The muffle is introduced by a side square opening at F. Pl. X. The top of this furnace is quite flat, and is covered by a very large thick square brick, inclosed in an iron rim, which simply lies upon it. The iron rim supports a handle by which the cover may be conveniently removed.

The center of this range is a very powerful *Draught Melting Furnace*. G is the body of the furnace, which is nearly in the form of a double cube. The upper part of it is formed by a bank of brick work, H H. Pl. X. and XI. projecting forward in an inclined plane upon the common level of the top of the whole range of furnaces, and cut down in the center, forming the large square opening at H, Pl. X. which looks down into the body of the furnace. This sloping direction of the upper opening gives a very convenient access to the fire for adding fuel and managing the crucibles, and the whole opening is closed by a thick brick similar to that which covers the muffle furnace. Opposite the center of the opening at H, Pl. X. is the chimney of the melting furnace, (represented by a very dark shading) which goes horizontally for a few inches and then forms the middle-

most of the five perpendicular chimnies. This is the only chimney the draught of which is never disturbed by the reception of any other flue. At the lower part of the ash-pit of this furnace is seen a square hole in Pl. X. which opens from behind, and is the termination of the brick canal, *a*. Pl. XI. which runs beneath the floor of the laboratory, and communicates with the outer air at *b b*. The use of this is to afford an ample supply of air to the furnace from without (and consequently cooler) which much increases its force; and also, more particularly, to allow the operator when standing before the furnace, to put a board to intercept the draught from the room to the ash-pit, which in winter is very troublesome from the chill which the cold air gives to the legs in rushing by. The grate of this, as of all the other furnaces, is not fixed in the brick work, but is supported merely by two iron bars a little below the bottom of the body of the furnace, upon which it slides in with ease, and when worn out or damaged, may be entirely drawn away by the opening of the ash-pit, and another put in its place. This is particularly useful in the melting furnace, as the intense heat is very apt to damage and destroy the bars of the grate.

I is a furnace for *Naked Distillation*. One side of it is cut down the middle to admit the beak of an earthen retort, and pieces of thick brick properly hollowed are introduced over and under the beak to fill up the cavity. A perpendicular section of this furnace is given in Pl. XII. Fig. 94, which is introduced chiefly as giving the proportions between the body of the furnace, the ash-pit, and the flues, which will answer for all.

K is a *Digesting Sand Bath*, or square flat-bottomed iron pot, set over a small furnace and filled with sand. On it evaporating pans and any other glass vessel may be conveniently placed, to receive a safe and gradual heat. The flame in this instance does not immediately proceed from the fuel to the chimney, but is caused to pass again round the iron pan, as in the outline plan K. Pl. XI. The pan is also shewn in Pl. XII. Fig. 93.

L is a common *Sand Bath Furnace*. Instead of the sand bath a boiler may be set over the fire when wanted.

M is a flat surface level with the top of all the furnaces, on which any thing may be set away, or which will very conveniently support a portable furnace, and for this latter purpose a side opening is made in the upright chimney, to which it is contiguous, which opens into it, about the same height as the flue D, on the opposite side.

Near the top of the room are two square doors represented on each side of O, Pl. X. which communicate with each of the upright chimnies next the centre one, and may be opened occasionally to let out any noxious fumes, or to insert the pipe of a portable furnace.

The whole of this range of furnaces, as already mentioned, is fronted with a solid screen, or kind of awning of masonry, which springs from the cieling contiguous with the wall of the room, and comes down in a sloping direction so far forwards as to project over the front of the furnaces, and as low down as will admit a person to stand conveniently under the lower margin. This screen, NN, Pl. X. is represented as broken away both in front of the upper part of the flue D, and also of the upper part of the face of the five perpendicular chimnies, so as to shew the doors on each side of O, which otherwise would be hid. All smoke and noxious fumes therefore, which escape from this part of the laboratory, are caught by the screen, and rising to the top may readily be carried off by opening one of these doors.

Pl. XII. Fig. 92. represents the iron door of the still and sand-bath furnaces, which is double, the inner one being connected to the outer by a hinge, which causes it to open and shut at the same time. The lower door also is somewhat uncommon in construction, having a circular opening round which revolves an iron plate, partly perforated, so as to act as a register.

Fig. 95, 96, 97, 98, are *Fire Tongs* of various construction.

GAS. (*Apparatus for saturating fluids with.*)

It is often required in chemical operations to impregnate water or other liquids with one or other of the gasses, and a great many ingenious contrivances have been invented for the purpose. To effect it compleatly, the liquid must be so situated as to have a quantity of the gas confined with it in a close vessel, or constantly passing through it, and the absorption is always much assisted by artificial pressure or agitation, or both together.

Some gasses, such as carbonic acid gas or sulphuretted hydrogen, are so soluble in water that this fluid may be made to take up a considerable quantity simply by being shaken together in a close phial, and therefore for extemporaneous purposes, where the waste of a little of the gas is not an object, nothing more is necessary than to fill a common phial quite full of distilled water, to invert it in a small tea-cup

full of the same, to introduce under the mouth the tube of a *proof bottle*, and to throw up as much air as will expell about half the water from the phial; then keeping the finger close upon the mouth of the phial shake it very violently for a minute or two, and so much of the gas will be absorbed as to produce a very sensible vacuum in the phial. But as large quantities of aerated water cannot be prepared in this way, some machine is required to present successively to the same portion of fluid a fresh supply of gas, till it is as fully saturated as can be done under the degree of pressure employed.

The machine invented by Dr. Nooth, and known by the name of *Nooth's Apparatus*, has long been in common use for this purpose, and though it has some defects, it is on the whole a very useful apparatus. This machine, Pl. III. Fig. 46. consists of three vessels; the lowest, *a*, has a very broad flat bottom, that the whole may stand steadily. It contains the materials from which the gas is given out (marble dust and dilute muriatic acid for example, when a carbonated liquid is to be prepared, which is most commonly the case) of which a fresh supply is from time to time to be added through the opening made for that purpose, the stopper of which must fit very accurately. The gas passes through the valve *b*, into the vessel *c*, which contains the liquor to be impregnated. A section of the valve is represented separately in Fig. 45, and consists of a portion of a glass tube *b*, open at bottom, and closed at top, but perforated with several small holes, and which fits closely into the bottom of the vessel *a a*, that contains the liquor. The inner part of the tube *b*, is partly filled with two thick pieces of glass tube (represented by the deeper shading) with the small perforations *c* and *e*. The space between these two pieces is occupied by a glass valve in the form of a plano-convex lens, which lies flat upon the lower piece on which it smoothly fits, but is easily lifted up by the influx of gas from below, sufficient to allow it to pass; whilst it is so far confined that it cannot be turned over, but immediately falls down again in its proper place.

The middle vessel *c* (Fig. 46) has a glass stop-cock to draw off the liquor, and into it dips the end of an upper vessel *d*, which is intended to afford a small pressure on the gas in *c*, and also a constant circulation of the liquor from one to the other. At the top of *d* is a stopper, which is the only joining of the whole apparatus which is not required to fit very tight, as it is only intended to allow the excess of gas to escape; and indeed it should fit rather loosely, otherwise it allows so great a quantity of gas to collect within, that when it is forced up it is often projected to some distance. A loose cork answers as well. In using this apparatus, so much liquor should be poured into the middle vessel as to rise some way above the bottom of the tube of the upper vessel that dips down. The gas being then generated in the lower vessel *a*, it rises through the water of *c*, up to the juncture between *c* and *d*, where, not being able to escape, it accumulates, and by its pressure causes the liquor to flow through the bent tube into *d*, driving before it the atmospherical air. When the liquor has thus fallen in *c*, below the level of the dip of the bent tube, the gas rises through this tube, and in its passage agitates the liquor in *d*, and sends down a portion; and thus a constant agitation is kept up which highly favours the absorption.

The chief inconvenience of this machine is the number of parts of which it is formed, and the accurate grinding required for all the pieces that fit, which makes the apparatus expensive, and not easily repaired when any portion is broken.

A much simpler, cheaper, and equally good apparatus is that represented in Pl. III. Fig. 47. invented by the late Dr. Hamilton. It consists of three parts. *a* is a tubulated retort, with a short thick neck, fitting accurately into the decanter-shaped vessel *b*. The retort contains the substances whence the gas is procured, and has the advantage over Nooth's apparatus, in allowing heat to be applied, so that it will serve for making liquid oxy-muriatic acid, and for many other purposes.

The upper vessel *c* fits into the decanter, and besides has a long glass tube proceeding from the bottom, and ground accurately to it, which reaches to the bottom of *b*. The vessel *c* should hold about as much as the decanter. The use of this apparatus is obvious. The decanter is first filled with the water to be saturated nearly as high as the point where the retort enters, and the advantage of the decanter-form is that very little common air is then left in. The influx of gas from the retort accumulating at the top of *b* drives the contained liquor up the tube *d*, into the vessel *c*, till the decanter is quite empty of water, and only filled with the gas, on which a considerable pressure is therefore always kept up.

This apparatus is not readily deranged, its parts are strong and simple, and it will bear as much shaking as Nooth's machine, care being

taken to keep the retort itself as still as possible, that none of its contents mix with those of the decanter.

Another apparatus, similar to Dr. Nooth's, but somewhat better, is formed by the vessels *a*, *b* and *d* of Fig. 42, adding to the top of *d* the vessel *a* of Fig. 44. A valve is placed between *b* and *d* similar to that of Nooth's apparatus. But as these vessels also belong to an improved *Woulfe's Apparatus*, we shall mention them under that article.

It should be observed however that the utmost effect of the best glass vessels in impregnating water with carbonic acid, or any other gas, is very far short of the power of the forcing pump; and it is by this latter method that all the brisk foaming carbonated waters are made which are consumed so largely under the names of artificial Seltzer, Soda, Pyrmont waters, &c. Mr. Paul, of Geneva, appears to have been the first who adopted this excellent method of making the artificial mineral waters.

GAZOMETER.

These are vessels of various shapes and contrivance, intended as reservoirs to hold a pretty large quantity of gas (several gallons for example) and are indispensible in a well-furnished laboratory. They are made of thin tinned iron-plate, well japanned on both sides, and most of them have some contrivance for measuring the quantity of gas which they contain. We shall describe three kinds of gazometer, all of which are in common use and answer very well.

Pl. V. Fig. 61 and 62 represent a view and section of a common gazometer. The letters in each refer to the same parts. *a a* is the outer pail or circular vessel, with a spout at top. Two tubes *d* and *e* (each fitted with a stop-cock externally) are firmly soldered to the sides of the pail: the tube *d* penetrates at the bottom of the pail and proceeds to the center where it joins the termination of the tube *e*, which enters the top of the pail and proceeds downwards; and from the place of junction the upright tube *g* rises through the middle of the pail a little above the level of its upper rim. The vessel *b* is a cylinder open only at the bottom, and of less diameter than the pail, into which it is inverted, and can move up and down freely. This cylinder has a solid stem *c*, which passes through a hole in the wooden cross bar of the frame round the top of the pail, and serves both to keep the cylinder in a perpendicular direction when moving up and down, and to indicate the quantity of inclosed gas by the graduation on its surface. The weight of the cylinder is counterpoised by weights put in a scale dish, which is connected to the top of the cylinder by a cord and pulley. The pail has besides an opening through its bottom closed by a separate stop-cock *f*, by which the water may be drawn off. The whole apparatus is conveniently supported on a heavy wooden stool. It is not essential to have both the tubes *e* and *d* for the filling and emptying of the gazometer, but it is more convenient, as they are of different heights. To use this gazometer, first let the cylinder fall to the bottom of the pail, and pour water into the spout of the latter till it is quite full. Then shut the cock *e* and open *d* and connect with it the tube which conveys the gas immediately from the retort or other vessel in which it is produced; or, if more convenient, shut *d* and convey the gas through *e*. In either case the gas rises through the upright tube *g* to the top of the cylinder *b*, which it gradually lifts up, and care must be taken to keep in the scale dish sufficient weight to allow the cylinder to move with perfect freedom. When all the gas is obtained, shut the cock through which it passed, and it remains in the inverted cylinder ready for use. To take out a portion of it, connect with either of the stop-cocks a bent-tube dipping under the jar, or whatever vessel it is to be received in inverted over water, and at the same time lift up the scale dish, on which the cylinder will press down by its own weight, and force out the contained air. The tube which terminates at *e* is a very convenient height for a blow-pipe, either for common air or especially for oxygen gas, and straight blow-pipe tubes are made for the purpose, which may be of the size to fit on closely, or may easily be made to do so, by the intervention of a cork. It should be observed that in this apparatus the weight of the cylinder is constantly increasing in proportion as it fills with gas, and rises out of the water, and consequently if the counterpoising weight is only equal to that of the cylinder in the first moment of its rise, the gas becomes gradually more and more compressed by that part of the weight of the cylinder which is not counterpoised, and if its quantity is then estimated by the bulk which it occupies, without making allowance for the increasing pressure, a material error would arise. To compensate for this increasing weight of the cylinder, and render a scale of equal graduations accurate, some have ingeniously adopted the plan of a spiral pulley to the cord, which has the effect of gradually

increasing the weight of the counterpoise in proportion as the cylinder rises from the water.

Fig. 63 is a gazometer on the same principle as Fig. 61 & 2, and differing from it only in this single circumstance, viz. that the outer pail has the greater part of its capacity filled by a hollow cylinder h. h. which is closed on all sides except a perforation through its center to admit the upright air-tube *g*, and is firmly soldered to the bottom of the pail. The use of this fixed cylinder *h* is to lessen the bulk of water necessary to confine the gas in the moveable cylinder *b*, and which in the first described gazometer is often inconvenient from its weight, as it fills the entire capacity of the pail except the small space occupied by the mere substance of that part of the cylinder *b* which is immersed. Whereas in Fig. 63 the quantity of water required is only that which will fill the space *a a* between the pail and the fixed cylinder *h. h.* in which space the gas-cylinder *b* moves up and down freely. The vaulted form of the upper part of this latter cylinder is also an improvement, as it admits of the air remaining in it being more completely emptied by the pipe *g* before a fresh distillation of gas is begun.

Plate. VI. Fig. 64 is a very ingenious and useful gas-holder, with a cistern at the upper part, which on the whole combines more conveniences in the management of gasses than any other. It consists of a tinned iron hollow cylinder *a* highly japanned, on the top of which is supported by three solid legs *h. h.* the pan or cistern *b.* (the glass jar *c* is not a part of this apparatus, but is only shewn in this place as convenient for many experiments). The hollow cylinder *a* is plain in the inside, except a small projection at the bottom of *d*. It has the following six openings into it. From the top proceed the pipes *f* & *g*, each of which also communicates separately with the pan *b*. (the tube *g* is often made parallel with *f*, which answers as well.) The short tube *e* also opens directly into the upper part of the cylinder. *d* is a pretty large opening formed by a short pipe which enters the cylinder at an angle of about 45°. and passes down for an inch or two in the same direction. At this angle the water will not run out through it from the cylinder, provided all the tubes that would admit the pressure of the external air are closed. This opening *d*, has a stopper which may be screwed on when wanted. Besides these four openings, which are essential to the apparatus, there are two others, *k. k.* one at top and the other at bottom that communicate solely with the graduated glass tube *i*, which is strongly soldered into *k. k.* which are of brass. The use of this is to shew by inspection of the glass tube the level of the water within the cylinder, and consequently the quantity of gas which it contains. The usual capacity of the cylinder for experimental purposes is about 12 quarts, which are marked on a paper scale cemented to one side of the glass tube.

To fill this apparatus, first stop the openings *d* and *e*, and open *f* and *g*, then pour water into the pan *b*, which will fall down into the cylinder by one of the open tubes, whilst the air which it contained will escape by the other. When the cylinder *a* is quite full of water, which is known by inspecting the glass tube, stop the cocks at *f* and *g*, and open *d*, and the water (as already mentioned) will not flow out. Then introduce the beak of the retort or other conducting tube, so deep into *d*, that it projects beyond the inner edge, and begin the production of the gas. As this rises into *a*, it displaces an equal quantity of water, which *now* escapes through *d*, by the side of the tube that brings the gas. When the gazometer is so full that the level of the water falls to the bottom of the glass scale, shut the tube *d*, and the machine may then be conveyed any where without danger of losing any of the gas.

This apparatus will answer a variety of purposes. If, for example, a jar or any other vessel is to be filled with the gas, first fill the jar with water and invert it in the pan *b*, which is also to be filled. Then open the cocks at *f* and *g*, and the gas will rise into the jar by one tube and the water sink into the cylinder by another. An empty bladder may be filled with the gas in the same manner by screwing or otherwise fastening the neck upon one opening and letting water fall down the other; or it may be more conveniently fastened to the side opening *e*, and then only one of the upper cocks must be opened to let water down. The opening *e*, is also very convenient for supplying a blow-pipe, and for this purpose the flexible tube Fig. 68 may be fastened upon *e*. The glass vessel *c* furnishes a convenient method of shewthe deflagration of iron, phosphorus, &c. in oxygen gas without risk to the vessel. It is quite open at the bottom, and has an opening of moderate size at the top, to which is fitted a cork furnished with a stop-cock. To fill it with oxygen from the gazometer, first place it on the pan full of water, *b*, and through the stop-cock suck up the air till the water rises, and fills it entirely, and then turn the cock while the lips are still upon it. The jar is thus

filled with water, after which the oxygen is let up by opening the cocks *f* & *g* as already deſcribed. Then remove the ſtop-cock cork and immediately ſubſtitute another cork previouſly fitted to the jar, and having the lighted iron wire ſuſpended from it. The moment it is in the jar of oxygen, the iron takes fire and burns with the phenomena deſcribed under that metal.

It may be obſerved that as the only intention of the ſtop-cock in the cork is to enable the jar to be filled with water, any other method of doing this will anſwer as well.

GUN-BARREL APPARATUS. This term is given by ſome to the following.

HYDROGEN, *Apparatus for procuring.*

Under the article HYDROGEN we have mentioned that it is obtained in abundance by paſſing the ſteam of water over red-hot iron, and an ingenious apparatus for the purpoſe was invented by Dr. Prieſtley, which has been ſince applied to a number of other experiments of reſearch, where the object has been to ſend any kind of vapour through a tube containing any ſubſtance heated red-hot. The apparatus is ſimply the following: Pl. II. Fig. 41. *a* is a retort, the beak of which is luted into one end of the tube *b b*, which lies acroſs a portable furnace in ſuch a manner that the middle part may be heated red-hot, whilſt each extremity is comparatively cool. *c* is a bent tube luted to the other end of *b*, and which may be directed under an inverted jar in a pneumatic trough, or any other veſſel intended for the reception of gaſſes. The middle of the tube *b*, which lies over the furnace, is filled with iron wire or turnings cloſely rammed. When this part of the tube is fully red-hot the water in the retort *a* is made to boil, by putting a lamp beneath it, and the ſteam paſſing over the heated iron is decompoſed, and the hydrogen produced by this method is given out copiouſly at the bent tube *c*. In this experiment the tube *b* is generally a plain iron pipe, formed out of a gun-barrel, by filing off the breech. In ſome caſes the tube may be of earth, but it ſhould be remembered that even the cloſeſt pottery is ſomewhat porous at a red-heat, ſo that it ſhould be incloſed in another tube of green glaſs or metal.

A gun-barrel tube for the ſame purpoſe is ſeen at *g*, Fig. 77. Pl. VIII. traverſing a Black's furnace, and is mentioned under the article furnace. Where the ſubſtance to be heated in the tube is of a kind that will not keep its place, as cloſely rammed iron wire will, the charge may be confined by a pellet of wet clay at each end, which as it dries ſhrinks and cracks, ſo as to allow the paſſage of aqueous vapour and gas through it, but confines ſolid or pulverulent bodies.

HYDROMETER. See SPECIFIC GRAVITY.

JAR.

Glaſs jars of a cylindrical ſhape or nearly ſo, are indiſpenſably neceſſary in the laboratory, both for experiments on gaſſes, and for holding liquors in all the common operations of filtering, precipitation, mixture, &c. For the gaſſes, the jars are uſually plain cylinders, Fig. 16. Pl. I. of various length and capacity, which ſtand ſteadily enough when inverted over water, and the margin of the open end is generally ground ſmooth, that when any flat plate, or a circular bit of card, is preſſed upon it, the water may not drop out when the jar is inverted. For experiments with mercury, the jars ſhould be ſmaller and thicker, and to ſtand very ſteadily, jars are ſometimes wider at bottom, as in Fig. 18. The moſt convenient jars for mixtures and precipitation are ſuch as Fig. 19, or as thoſe which are repreſented ſtanding under the four funnels in Fig. 65. Pl. VI. theſe being broad at bottom, any precipitate can be more thoroughly edulcorated than in any veſſel of the wine-glaſs ſhape. The thick jar for exploſions with the electric ſpark, ſuch as in Fig. 67, has been already deſcribed under the article *Detonating Jar*.

LABORATORY.

A convenient well-furniſhed laboratory is, of courſe, a principal object with the chemiſt, though it may be ſome ſatisfaction for the lover of this attractive ſcience, whoſe means of indulging it are very limited, to know that moſt of the admirable reſearches of Scheele, Prieſtley, Crawford, and Berthollet, were carried on with ſuch ſimple and cheap apparatus as moſt perſons can command. Neverthleſs it is of extreme advantage to have a well-furniſhed laboratory; accurate (and therefore expenſive) inſtruments are almoſt indiſpenſible in many experiments of reſearch; and if we have ſimplified many of the long and embarraſſing proceſſes of the older chemiſts, we have, on the other hand, added moſt abundantly to the field of chemical enquiry by the knowledge of gaſſeous bodies, and equally to the number of inſtruments now neceſſary to carry on chemical reſearches.

It may not be unacceptable to thoſe who are entering upon chemical ſtudies, to give a ſhort liſt of thoſe articles of furniture which may be onſidered as almoſt indiſpenſible to carry on a eneral courſe of experiments; omitting how-

ever ſeveral nice and complicated inſtruments, which have been deviſed for many experiments of reſearch, ſuch as, for example, the compoſition of water.

If the chemiſt has opportunity of building a laboratory, or of converting a conſiderable part of a ſmall houſe to the purpoſe, it will be more convenient to have both a ground floor and an upper ſtory; on the ground floor he may build his brick furnaces, keep charcoal and other fuel, grind and ſift different materials, evaporate large quantities, and do all thoſe things which make much duſt or fumes, and reſerve the upper room for the nicer and cleaner experiments. But if he can only devote a ſingle room to chemical uſes, it is on the whole preferable to have it above the level of the ground, on account of its being much drier, for a damp air ruſts every thing of iron and ſteel, ſpoils the ſcale-beams, looſens the gummed labels to the bottles, renders many ſalts damp and deliqueſcent, and produces many other inconveniences. The only advantage of a ground floor is the greater convenience of bringing water (which is abundantly required) but this is not at all counterbalanced by the trouble of dampneſs.

The firſt object to be conſidered is the mode of applying heat, or the ſelection of furnaces. If the chemiſt has only a ſingle room with a common fire-place, the latter ſhould be made as wide as poſſible, and the grate removed to give room for one or two portable furnaces. Theſe may be a *Black's Furnace* with ſand-bath, earthen tube, muffle and other appurtenances, and a *ſmall Blaſt*, which will ſuffice for moſt operations, beſides which it is extremely convenient to have one or two large black lead pots with a grate near the bottom, an aſh-hole cut below it, and the top deeply indented in the form of battlements, over which a large evaporating pan or other veſſel may be ſet, and heated by charcoal. It is a great ſaving of room to have an iron flue hanging a few feet from the ground, and running up in front of the chimney-piece, and penetrating into the chimney near the top of the room, under which a ſmall chamber furnace or a charcoal pot may be ſet, without encumbering the fire-place. The chimney of the Black's furnace ſhould be lengthened by an iron pipe of at leaſt 6 or 8 feet long, and fixed up in the chimney of the room by iron cramps, which increaſes its draught prodigiouſly.

The room ſhould be amply furniſhed with ſhelves for bottles and glaſs apparatus, and with as many or as large deal tables as can conveniently ſtand in it, one of which ſhould be ſubſtantial and heavy, or elſe a kitchen dreſſer may be put up, with drawers below. A ſmall ſet of drawers ſuch as apothecaries uſe, will be highly convenient. If poſſible, a ſtone ſink ſhould be placed at one corner of the room with a ſupply of clear water, and conveniences for waſhing and draining bottles, &c. A ſolid block of wood is alſo uſeful, for ſupporting a mortar when pounding hard ſubſtances, and in which an iron anvil may be ſtuck when wanted.

Theſe being arranged, the chemiſt muſt furniſh himſelf with the moſt uſeful apparatus, of which the following are the principal articles: the deſcription of each individual article with the kind to be preferred, will be found under their reſpective heads:

A gazometer, with the connecting tubes, blow-pipe, &c.

A bladder, or ſilk bag, with ſtop-cock fitting the above.

A pneumatic water trough.

A copper ſtill with worm-tub, the ſtill fitting into the top of the Black's furnace.

A blow-pipe, with ſpoon, &c.

Lamps—an Argand, and others of common conſtruction for oil and alcohol.

An apparatus for drying precipitates by ſteam.

Scales and weights.

Large and ſmall iron ſtands for retorts, &c.

Mortars—one of hard ſteel, one of bell-metal, and one or two of Wedgewood ware.

A ſilver crucible and ſpatula.

A platina crucible and ſpatula.

A jointed iron tube for conveying gaſſes.

The following articles in glaſs:

Retorts of different ſizes, plain and ſtoppered, and long-necked for gaſſes.

Receivers to fit the above, plain and ſtoppered, with or without an adopter.

Plain jars for gaſſes, different ſizes.

Lipped jars for mixtures, precipitates, &c.

A graduated eudiometer jar.

Bell receivers, two or three ſizes.

Proof bottles.

Capſules or ſmall evaporating cups.

Water glaſſes (ſuch as are uſed at table) which are very convenient for gentle evaporations.

Florence flaſks.

Matraſſes—two or three very ſmall, and others of common ſize, round and flat-bottomed.

Funnels—ribbed, and one plain with a very long neck for charging retorts.

Wine-glaſſes—common or lipped.

Watch-glasses, for evaporating minute quantities at a very gentle heat.

Common decanters.

A bottle for specific gravity of fluids.

Phials of all sizes, plain and with ground stoppers.

Plain glass tube of various thickness and bore, out of which may easily be made

- Syphon tubes.
- Bent tubes for gasses.
- Capillary tubes, for dropping liquids, and various other useful articles.

A gas-saturating apparatus.

A Woulfe's apparatus.

A tube of safety, separate (Fig. 60).

A barometer.

Thermometers—common, and with the bulb naked, to dip into liquors.

The following in Earthen-ware:

Crucibles—Hessian, common, and black-lead, of different sizes and shapes, with stands and covers.

Retorts.

Retort-stands (such as Fig. 25 inverted).

Cupels.

Wedgewood evaporating dishes—a set.

White basons with lips, different sizes.

Common white cups and saucers.

Tubes—straight and bent.

Porcelain spoons.

Ditto rods, for stirring corrosive fluids.

Several stone ware jars with tin covers, for holding salts, &c.

Also the following sundries:

Wire—different sizes and kinds, viz. iron, copper, brass, silver, and platina.

Gold, silver, and brass leaf—tinfoil.

Wooden tripod stands for receivers, &c.

Fire tongs—various shapes.

Steel spatula and pallet knives.

Iron ladles

Diamond for scratching glass.

Files—flat, three-cornered, and rat-tailed.

Hammers.

A vice and anvil.

Pincers.

Shears and scissars.

A magnet.

Sieves.

Filtering paper.

Corks.

Bladders—spirit varnish—sponge—tow—linen—flannel.

Windsor and common bricks—tiles—sand.

Lutes of various kinds. (See article CEMENTS.

For more extensive and delicate researches it it is also necessary to have

A mercurial pneumatic trough.

A mercurial gazometer.

A burning lens of considerable power.

An electrical apparatus.

A Galvanic apparatus.

A Detonating jar.

A glass or silver alembic.

The fuel to be employed has been already mentioned under the article Furnace, and a supply should be kept near at hand, broken down ready for use.

With regard to the different substances or reagents to be kept, the chemist will, of course, wish to have a specimen of all the simple or individual substances, such as the acids, earths, metals, &c. but it may not be unacceptable to add a list of those simple and compound substances which are of general use, and which therefore ought also to stand on the shelves.

For many purposes the ordinary degree of purity in which these substances are obtained by the common processes is sufficient; so, for example, the small quantity of potash in common sulphuric acid, and of iron in common muriatic acid, seldom interferes with any of the uses to which those reagents are applied; but it is also necessary frequently to have them in the utmost purity when employed as tests for delicate purposes. The chemist will therefore find it of advantage to reserve a separate set of a few of the most necessary reagents in their utmost purity, and if only employed when absolutely requisite, a very moderate quantity will suffice. In the subjoined list we have distinguished by the word *pure* those substances which require particular pains to be obtained absolutely pure, and the methods of doing it will be found under the respective articles. Mixtures of each of the stronger acids and water in two or three different and known proportions should also be kept.

(N. B. *The letter* D *implies that the Dry substance should be kept, and* S, *that it should be in Solution.)*

Sulphuric acid,	pure
Ditto	common
Nitric acid,	pure and boiled
Ditto	common and boiled
Ditto	fuming
Muriatic acid,	pure
Ditto	common

Oxymuriatic Acid
(This should be kept in the dark)
Phosphoric Acid, pure, from Phosphorus. S.
Acetic Acid
Distilled Vinegar
Ditto, concentrated by frost
Oxalic Acid. S.
Tartareous Acid. S.
Sulphat of Potash. D. & S.
——— Soda. D. & S.
——— Barytes. D.
——— Alumine. S.
——— Strontian. D.
Alum. D. & S.
Nitrat of Potash. D. & S.
——— Ammonia. D.
——— Barytes. S.
——— Strontian. S.
Muriat of Soda. D. & S.
——— Ammonia. D. & S.
——— Strontian. S.
——— Barytes. S.
——— Lime. D. & S.
——— Alumine. S.
Oxymuriat of Potash. D.
Phosphat of Soda. D. & S.
——— Ammonia. D.
Acetite of Barytes. S.
——— Alumine. S.
Oxalat of Ammonia. S.
Cream of Tartar. D.
Crude Tartar. D.
Tincture of Galls
Borax. D. & S.
Ditto, vitrified
Fluat of Ammonia. S.
Succinat of Ammonia. S.
Prussiat of Potash, pure and dry
(This should be kept in the dark)
Prussiat of Lime. S.
Plaster of Paris
White Marble
Bone-Ash
Fluor Spar
Potash, pure. S.
Ditto, common caustic. S.
Pearlash. D. & S.
Salt of Tartar. D. & S.
Super-Carbonat of Potash. D.
Carbonat of Soda. D. & S.
Ditto fully dried
Ammonia, pure
Carbonat of Ammonia. D. & S.
Super-Carbonat of ditto. D.
Lime
Lime-water
Barytic-water
Strontian-water
Carbonat of Magnesia
Hydro-sulphuretted Water
Hydro-sulphuret of Soda. S.
——— ——— Ammonia. S.
Sulphuret of Potash. D.
White Arsenic. D. & S.
Manganese, Black Oxyd of
Mercury
Ditto, Red Oxyd of
Nitrat of Mercury. S.
Corrosive Muriat of ditto. D. & S.
Zinc, in sticks and granulated
Tin ditto ditto
Muriat of Tin
Lead
Minium and Litharge
Nitrat of Lead. S.
Acetite of ditto. S.
Iron, Filings, Turnings, Wire
Sulphuret of Iron for Sulphuretted Hyd. Gas
Sulphat of Iron. D. & S.
Ditto, saturated with nitrous Gas
Muriat of Iron
Copper, Sheet, Wire
Nitrat of Copper. D. & S.
Silver, Leaf and Wire
Nitrat of Silver. S.
Sulphat of ditto. S.
Acetite of ditto. S.
Gold-leaf
Nitro-muriat of Gold
——— Platina
Sulphur
Phosphorus
Alcohol, concentrated and common
Sulphuric Ether
Litmus Tincture
Turmeric
Brazil Wood
Gall Nut
Catechu
Isinglass
Olive Oil
Linseed Oil, Drying
Oil of Turpentine
Black Flux
Distilled Water, in great plenty.

LAMPS. A lamp is a most convenient article of chemical apparatus for moderate heat, on account of the steadiness and durability of the heat which it gives; and a vast number of experiments may be performed by it. The Argand lamp well trimmed will bring to a boiling heat a pint or two of liquid in a glass

or metallic vessel, and may therefore be used for numerous distillations, particularly in those cases where the rest of the apparatus is required to be kept cool. To increase the heat of this lamp some ingenious artists have invented double concentric wicks, which renders it equal to a sand-heat, but the supports of the wicks are apt to be out of order, owing to the fusion of the solder. Smaller lamps are also required, and for these, alcohol is a very valuable fuel, as its flame is perfectly clean.

MATRASS. This is a thin glass vessel of the shape of a flask, which will bear a lamp-heat at bottom without breaking. It is either round at the bottom as in Fig. 57. *a*. or flattened a little. Fig. 48. Fig. 18. Pl. I. is a very useful small matrass of about 2 ounces capacity.

MORTAR. This is a most essential article in a laboratory, to reduce to powder a variety of substances, and the material of which it is made is of considerable consequence. Very hard bodies, such as the gems, quartz-crystal, &c. can only be ground to powder in a mortar of agate, or flint, or some other hard siliceous stone. They must previously however be crushed into fragments, either in a steel mortar, or wrapped up in many folds of strong paper, and bruised on an anvil with a heavy hammer. The fragments are then collected, and put into the flint mortar with a little water, and a very long continued friction is required to bring it to an impalpable powder. It should always be remembered that when a very hard body is ground to powder, the friction wears the mortar as well as the substance pulverized, consequently for delicate experiments it is necessary to weigh the mortar before and after the process, and allow for the loss of weight by an equivalent addition to the powder obtained. Hence too the composition of the mortar itself should previously be known, and by the analysis of Klaproth it appears that black flint and agate are so nearly pure silex, that the minute quantity of their other constituent parts may be entirely neglected.

For grinding substances of moderate hardness, steel mortars with very smooth pestles of the same materials, are kept in some of the shops. Very useful mortars are also made of cast iron, which are very hard, but are not finished quite so smooth as those of steel. Large mortars of this kind are used by the druggists for pounding barks, woods, &c. and to lessen the manual labour, the pestle is fastened to the end of a flexible wooden pole, which hangs over the mortar, by the elasticity of which the pestle is lifted up again to the proper height after the stroke is made. For lighter purposes very good mortars are made of bell-metal, with pestles either of the same or of iron. These are cast very smooth so that the material to be pounded does not stick to the sides. Most neutral salts may be conveniently pulverized in them, but their chemical action on the copper ought to be kept in mind, as (for example) if sal-ammoniac is left for some hours in a bell-metal mortar it becomes green by the oxyd of copper which it dissolves. These mortars are often fitted with wooden covers, perforated to admit the pestle, so as to prevent fragments from flying out by the stroke.

Mortars are also made of marble, glass, and Wedgwood ware. The latter are highly useful, being very hard, smooth, and not acted on by any chemical reagent. They will readily break, however, by a smart blow.

MUFFLE. Pl. I. Fig. 30. A muffle is a vaulted flat-bottomed earthen vessel, intended to be put in the midst of a furnace, of proper construction, so as to afford a space strongly heated, but protected from the actual contact of the fuel, in which small vessels of any kind may be set. The muffle is entirely open at one end, and closed at the other, and it has sometimes small side slits, to allow the freer access of the hot air. It is always set in a furnace with the open end directly opposite a side door, of the same arched shape, and which it touches, so as to prevent any of the fuel from getting in. The door for this purpose is seen in Pl. VIII. Fig. 77. & 78. *d*. and Fig. 83. *e*. The muffle will just slide in and out of these openings with ease, and iron bars or some other kind of support are placed in the furnace to keep it at the proper level. When the substance in the muffle is to be heated without access of air the stopper of the furnace may be thrust in upon it; but when a current of heated air from without is wanted to pass through the muffle, which is the case in assaying, the stopper of the furnace must be removed, and instead of it a small iron plate (like the flat part of a shovel with the edges a little turned up) is fixed on a level with the bottom of the opening, on which are heaped a number of long pieces of charcoal to block it up. These presently kindle by the heat of the furnace, so that the air which passes freely between them into the muffle is heated in its passage, and the muffle may be cooled at pleasure by taking away some of the pieces of charcoal. The small

crucibles used for assaying, are called *Cupels*. Fig. 28. & 29.

NOOTH's APPARATUS. See *Gas saturating Apparatus*.

OXYGEN *Combustion* in. A vessel very convenient for this purpose is shewn in Fig. 64. *c*. and is described under the article *Gazometer*.

PELICAN. Pl. II. Fig. 38. This is an old instrument now little used, intended for long digestions on a sand-bath, or other heat, with a contrivance for constantly returning on the materials at the bottom all the liquid of the menstruum which would otherwise evaporate by the heat. It is therefore a glass alembic, in which there are two pipes that collect the distilled liquor, and again enter the lower vessel. The small apparatus at Fig. 37. is for the same purpose, and is more convenient. Its construction is obvious.

PNEUMATIC TROUGH. See TROUGH. *Pneumatic*.

PRECIPITATING GLASS. Pl. I. Fig. 20. This is a very tall jar with a narrower part at the bottom, in which any precipitate when produced may collect by subsidence, and allow of the supernatant liquor to be decanted off with more ease. It is also a very useful glass in which to float the *Hydrometer*.

PROOF-BOTTLE. Pl. I. Fig. 13. 14. 15. This is a glass phial for procuring gasses, made thin and round at bottom, so as to bear moderate heat, and with a bent tube closely ground to it for conveying the gas under any inverted vessel. It has besides sometimes another opening solely for introducing the materials. This vessel is very useful for experimental purposes, where only moderately small quantities of gasses are wanted, and from materials that require no greater heat than a small spirit lamp or candle will produce. It is an improvement on the original cheap apparatus of Dr. Priestley, namely, a phial with a piece of bent glass tube thrust through the cork and properly cemented. This latter however will often answer every end, especially where no artificial heat is wanted, as in obtaining hydrogen from muriatic acid and zinc. It may be useful to mention, that corks are most conveniently perforated, and the hole made very smooth and neat, by the *rat-tailed file*. The joining of the tube and the cork may be made quite air-tight by sealing-wax.

PYROMETER. (*Wedgwood's*). See the article *Pyrometer* in the former part of this work.

RECEIVER, is a globe-shaped vessel, either plain or tubulated, used in the process of *distillation*. It receives the beak of the retort, or the adopter, if this is used. See Pl. I. Fig. 4. Pl. III. Fig. 42. *l*. Pl. IV. Fig. 59. *d*.

RECIPIENT, *Italian*, is a vessel like a teapot, intended for the separation of essential oils from the watery liquor on which they float.

REFRIGERATORY is that part of a *Distilling* Apparatus when the vapour is cooled and condensed. In the *Alembic* it is at the top of the apparatus; in the common Still it is the Worm-tub. See *Distilling Apparatus*.

RETORT is the common and most useful instrument for *Distillation*. See Pl. I. Fig. 2, 5, 11. Retorts with very long narrow necks Fig. 1. are made for heating those substances which are intended to yield any of the gasses, for here no width of vessel is wanted for the condensation of vapours, and the narrowness of the neck allows but little admixture of the external air. Retorts are made of glass, earthen-ware, and sometimes of iron or silver. A leaden retort is used for procuring fluoric acid.

REVERBERATORY FURNACE. See FURNACE.

SAND-BATH. See BATH.

SERPENTINE or WORM. See DISTILLING APPARATUS.

SOLAR HEAT. (*Apparatus for*). A very elegant and often most convenient method of applying heat is by the sun's rays through the means of a powerful lens or mirror. It unites the great advantages of simplicity and extreme power, and has been employed most happily by Dr. Priestley and other philosophers in several important experiments. Where the substance to be heated is to be at the same time debarred from the access of the external air, the vessel must be thin clear glass, that the cone of rays may be transmitted through with as little loss as possible. The heat produced by the most powerful glasses (such as that of Mr. Parker) appears fully to equal, in a small space, the effect of the blow-pipe fed with oxygen gas.

SPECIFIC GRAVITY, *Apparatus for*.

Though experiments on specific gravity do not absolutely belong to chemistry, it is necessary that the chemist be furnished with the means of ascertaining the specific gravity of both solids and fluids with tolerable accuracy, as it assists much in many chemical enquiries, and the effect of acids, alcohol, and some other reagents very materially depend on their degree of concentration which is known by their density or tenuity. Therefore the scales which the chemist employs should allow to be used hydro-

statically, or else he should be provided with an hydrometer, of which Mr. Nicholson's (or that in which the point of immersion is fixed) is by far the best. The specific gravity of fluids may also be very conveniently taken in the following way: take a small light bottle that stands firmly, and holds an ounce or two, or more, of water, the neck of which is stopped by a piece of barometer tube very accurately ground. Then counterpoise the empty bottle, and afterwards fill it entirely with distilled water at 60° recently boiled, till it rises a little in the bore of the tube and find the weight. For greater ease in calculation it will be as well (if it can be done) to bring the water exactly to that height in the tube, at which its weight will be 500 grains, or 1000, or 1500, or 2000, &c. but this is not essential. Then mark the height most accurately with a fine file on two opposite sides of the tube, and scratch on the bottle the weight both of the bottle and tube when empty, and of the quantity of water requisite to fill it to the mark. This will then serve for the specific gravity of all other fluids, as pure water is the standard of comparison for all bodies solid as well as fluid.

STILL. See DISTILLING *Apparatus*.

THERMOMETER. Several varieties of thermometer are made for philosophical purposes, and in many experiments, particularly all those connected with the subject of caloric, it is necessary to be well provided with them. To take in the entire range of thermometrical temperature from the most intense artificial cold to the boiling point of mercury requires a very long tube; but for most chemical purposes it is sufficiently high if it is graduated to about 10 degrees above the boiling point, which will reach the temperature of most saline solutions when boiling.

For experiments on intense cold, it is necessary to have a spirit thermometer graduated about 100°. below 0. and the lower extremity of the scale should be at some distance from the bulb, that the temperature may be observed without lifting the bulb out of any deep vessel that may contain the freezing mixture. The most delicate and sensible thermometers are made with a very small bulb, scarcely larger than the stem, and a tube of an extremely narrow bore, not larger than a horse-hair. For chemical purposes also the scale should either be scratched on the glass itself, or as this is difficult to be seen in a common light, an ivory scale should be attached, without reaching so low as the bulb, that the latter may be safely immersed in acid or corrosive liquors.

The thermometer scale has been differently divided by the original constructors, which often causes a good deal of trouble in comparing results of experiments made in different countries. Three scales are principally used: *Fahrenheit's*, which is employed in this country, in which the 0. is 32 degrees below the freezing point of water, and the interval between 0. and the boiling point of water is divided into 212 degrees, and consequently the freezing point of water is 32°: *Reaumur's*, which has the 0. at the freezing point of water, and divides the interval between this point and the water-boiling heat into 80 degrees: and *Celsius's*, originally used in Sweden, and since adopted in France under the name of the *Centigrade*, which has, like Reaumur's, the 0. at the freezing point of water, but divides the interval between this and water-boiling heat into 100 degrees. The reason why Fahrenheit fixed his scale so far below the water-freezing point was founded on an erroneous hypothesis relative to the real zero or point of absolute privation of heat; but however it has this advantage over the two others, which is, that the distinction between the positive and negative terms (or which express degrees above or below the zero) much less frequently occurs in any experiments, and scarcely ever in the register of natural cold in temperate climates, by which many accidental errors are avoided.

In Appendix II. we have given the corresponding degrees of those three thermometers, by which the reader may at once translate the degrees of Reaumur's and Celsius's into the equivalent of Fahrenheit, or vice versa.

* * * * *

A very ingenious thermometer has been invented by Mr. Leslie, which he calls a DIFFERENTIAL THERMOMETER, as it expresses not the absolute degree of heat, but the difference (when any exists) between the temperature of the two spots where its two bulbs are placed. Its use is explained under the article CALORIC.

The differential thermometer (Pl. IV. Fig. 54.) is made in the following way: select two thermometer tubes with bores rather wider than usual, and one a little wider than the other. Let the balls be blown as equal as the eye can judge and from .4 to .7 of an inch in diameter, and let the open end of the tube also be widened in a slight degree. The tubes must be of unequal length, the longest being nearly

twice the length of the other. Then introduce into the longer tube a little ſulphuric acid tinged with carmine, ſufficient to fill about an inch of its cavity, join the two tubes together by the blow-pipe, and when joined, bend them in the form of the letter U. with the bulbs about 3 or 4 inches aſunder, making one flexure juſt below the juncture of the two tubes, where the ſmall cavity (which is repreſented in the plate) facilitates the adjuſtment of the inſtrument, which by a little dexterity is performed by forcing a few globules of air by the heat of the hand from one bulb to the other. Attach a graduated ſcale to the ſhorter tube, making the zero about the middle of it, and adjuſt to it the quantity of air in each bulb, ſo that when the bulbs are at the ſame temperature, the upper ſurface of the coloured liquor may juſt correſpond with the zero. Sulphuric acid is choſen as the liquor interpoſed between the bulb, on account of its bearing any heat or cold that would be uſed without being evaporated or congealed.

In this inſtrument the air incloſed in the bulbs is the ſubſtance which, by its expanſion or contraction, cauſes the motion of the coloured liquor up or down the ſcale, and as gaſſes are much more expanſible than liquids, the inſtrument is ſooner affected by minute changes of heat. But as the two bulbs are of equal ſize, and both filled with air, and ſeparated from each other by the intervening liquor, it is obvious that when the temperature is the ſame in each bulb, be it high or low, the preſſure on each ſide of the liquor is alſo equal, and it muſt remain ſtationary: ſo that it can only move when one bulb is warmer than the other. Hence the particular and ſole uſe of this inſtrument as a *Differential Thermometer*. The lower part of the inſtrument (or the ſpace included between the two bends) is cemented to an upright ſtem by which it is ſupported.

TROUGH. *Pneumatic*.

In all the common operations of receiving and transferring gaſſes they are held in jars, or other veſſels, previouſly filled with water, and inverted over this fluid. It is therefore neceſſary to have ſome kind of water-veſſel large and deep enough entirely to immerſe the air-jar, that every particle of common air may be diſplaced by the water before it receives the gas to be operated on. Dr. Prieſtley's firſt water trough for this purpoſe was a common oval or round tub, but as a jar full of air ſtanding inverted over water and immerſed in it for any depth, would readily be overſet by the preſſure of the water, this ingenious philoſopher adapted a ſmall hanging ſhelf ſuſpended from the ſides of the tub, and ſinking below the level of the water, only juſt ſufficient to confine the gas in any jar ſtanding upon it. This plan has been adopted with ſome little improvements in the pneumatic water troughs commonly uſed, of which Fig. 49. Pl. IV. is one of the moſt convenient kinds. *a* is a deep oblong trough made of thin tinned iron well japanned, generally 18 inches long, 9 broad, and 14 deep. About 3½ inches from the top is a ſhelf of the ſame material, extending entirely acroſs the trough, and rather more than a third of its length, and fixed in its ſituation when required by two ſtrong wires. This ſhelf is given inverted in Fig. 50. to ſhew an oval rim projecting from it, in the center of which are two ſmall holes, the uſe of which is to ſecure and convey the gas into any veſſel ſet upon it (as the bottle in Fig. 49). This ſhelf has alſo two larger holes to receive two bottle ſupporters, Fig. 51. & *b*. Fig. 49. A trough of this ſize and conſtruction is very light when empty, and large enough for moſt operations.

Fig. 52. is a convenient trough for exhibiting experiments in the lecture room. It is ſimply a circular pan, 18 inches in diameter, with a looſe ſemicircular ſhelf ſupported to the requiſite height on three conical legs, on which a bell receiver is repreſented ſtanding. This pan is however too ſhallow to allow of any large veſſel to be immerſed, ſo that it muſt be previouſly immerſed in a deeper trough, and conveyed hither upon a plate or ſaucer.

Fig. 53. is a Mercurial Pneumatic Trough, which is indiſpenſible in moſt experiments on gaſſes abſorbable by water. It may be made either of a cloſe hard wood ſuch as mahogany, or cut out of a block of ordinary marble or freeſtone, or as is now more common, it is a thin iron caſe incloſed in wood. When made of wood it is often hollowed out of a ſingle piece, but if grooved and very neatly rabitted, it will anſwer nearly as well. In any caſe it ſhould alſo ſtand on a ſhallow wooden or iron diſh to catch the mercury, ſome of which is always ſpilling whatever care be uſed.

Theſe mercurial troughs muſt be made very ſolid to bear the great weight of metal that is required even for a very moderate ſized veſſel, and for the ſame reaſon and to ſave the great expence of the metal, they are always made much ſmaller than the water troughs. This will not appear an indifferent object when it is conſidered that half a hundred weight of this

metal will not occupy a ſpace greater than about two quarts, which is but a very ſcanty allowance of room for a trough for chemical purpoſes.

In order ſtill more to economize room and conſequently mercury, only one ſide of the trough is ſunk deep (as ſhewn at *a* by the dotted line in the plate) being equally convenient for the immerſion of a jar. The ſhelf in a trough of this conſtruction is on each ſide of the well. It is uſeful alſo to have an iron ſtem ſupporting a ſemicircular clip, ſcrewed or otherwiſe faſtened into the ſubſtance of the trough a little beyond the deep circular part of the well, to ſupport a jar when inverted and heavy with mercury. A ſmall glaſs tube open at both ends and drawn out capillary at one extremity, is an uſeful addition to this apparatus, to enable the operator to ſuck up and collect the ſmall globules of mercury which will always be ſcattered about during theſe experiments.

TUBE OF SAFETY. (Fig. 60). See WOULFE's APPARATUS.

WATER BATH. See BATH and ALEMBIC.

WELTER's TUBE, or *Tube of Safety*.

WORM TUB. See DISTILLING APPARATUS.

WOULFE's APPARATUS. The invention of this apparatus forms almoſt an æra in chemical diſcovery, ſo great and various is its utility. Before it was known, the only veſſels that chemiſts employed for diſtillations were, either the alembic with its refrigeratory, or the retort with its receiver. The former was devoted almoſt excluſively to the diſtillation of thoſe fluids which are readily condenſed by cooling, and are not attended with the production of much permanently elaſtic or difficultly-condenſible vapour, ſuch as water impregnated with the aromatic parts of vegetables, alcohol, &c. whilſt the retort with its glaſs receiver, was reſerved for the diſtillation of the ſtronger acids, and other ſubſtances accompanied by much uncondenſible vapour. But here a great inconvenience ſubſiſted, for either enormouſly large receivers were required, or a conſiderable number of them with double openings like aludels, or elſe it was neceſſary to avoid the rupture of the veſſels by having a ſmall hole, which could be opened occaſionally, when the quantity of confined vapour was judged to be too great. But even this did not anſwer the purpoſe of the chemiſt compleatly, for much of the vapour given out during theſe diſtillations, is only uncondenſible for want of finding water or ſome other ſubſtance with which it may unite, ſo that a large proportion of the products of diſtillation were totally waſted. In experiments of reſearch too the old apparatus was peculiarly defective, as the gaſſeous products, which are often by far the moſt intereſting, were entirely loſt.

Glauber was aware of many of the defects of the old apparatus, and as early as about the year 1655, gave a very ingenious method of ſubſtituting to the ſeries of perpendicular aludel-ſhaped receivers, a lateral ſeries of plain ſtone or earthen jars, each connected with the other by earthen tubes bent at right angles, and the covers of each jar having two holes, one to receive the tube bringing the vapour from the adjoining jar or the retort, and the other for the paſſage of the tube which conveyed the exceſs of this vapour into the next in ſucceſſion. This arrangement is preciſely that of the bottles of the modern Woulfe's apparatus, but the jars which Glauber uſed were empty, and ſet in a larger veſſel full of cold water, ſo as to be kept always cool. (See *Glauberi Opera, Vol.* 3. *Furni Novi Philoſophici ſive Deſcriptio Artis Diſtillatoriæ Novæ. Pars. I.*)

The great improvement made to this apparatus by the late Mr. Woulfe,[a] was to fill theſe lateral veſſels with water, into which he dipped the extremity of each tube, bringing into it the uncondenſed part of the vapour, by which means a vaſt quantity of product is ſaved, which even in Glauber's method could not be ultimately detained; ſo that by having a ſufficient bulk of water in one or more of theſe lateral veſſels, no part of the product can eſcape detention except that which cannot condenſe, either alone or when paſſed through any liquid. Even this too may readily be ſaved, by adding to the laſt in the ſeries of bottles a curved tube, which conveys the gas to the pneumatic trough or gazometer, where its nature may be examined.

Inſtead of having the mouths of the lateral bottles wide enough to admit both tubes (that is, the one which brings the vapour into the bottle, and the other which conveys the uncondenſed part of it out of the bottle) it is a great improvement to have the bottles blown with two openings, as in *g* and *i* Fig. 59, and ſometimes a third is added as in *a* Fig. 58, for a particular purpoſe which will be preſently mentioned.

The eſſential parts of this apparatus therefore

a Phil. Tranſ. for 1767.

are, a Retort or any other veſſel in which the materials are heated; a Receiver to detain that part of the product which is condenſible by mere cooling; and a bent Tube proceeding from the receiver to the bottom of a bottle placed by its ſide, and full, or nearly ſo, of water, or any other liquid. If more than one bottle is employed, theſe are ranged ſide by ſide, and connected with each other by bent tubes, each of which proceeds from the top of the bottle immediately preceding, and plunges to the bottom of the liquid of the bottle next in order. Every part of the apparatus is air-tight except the end the furtheſt from the retort, ſo that every particle of vapour or gas has to traverſe the whole ſeries of veſſels, and to paſs through the liquid in every one of the bottles before it eſcapes into the air; and thus if at all condenſible by the liquid uſed, it can hardly eſcape condenſation.

Another part however is neceſſary to the perfection of this apparatus. When the diſtillation is nearly over, and the production of gas or vapour ſlackens, or ceaſes altogether, a degree of vacuum is always made in the retort, owing to the cooling of the elaſtic vapour which it contains. This circumſtance cauſes a ſimilar vacuum in the receiver, to fill which, a ſtrong abſorption or ſuction of the liquid takes place from the firſt bottle back into the receiver through the bent tube that dips into the bottle. This again cauſes an equal vacuum in the firſt bottle, which is filled by abſorption of fluid from the ſecond bottle through the communicating tube, and ſo on to the laſt; ſo that the moment that abſorption begins, a retrograde motion takes place through the whole apparatus. The inconvenience of this is the mixture of the products that takes place; for if, for example, the diſtillation of nitric acid is the proceſs, after the materials in the retort have given out every thing, the receiver, which was at firſt left empty, contains the concentrated acid, and the bottles contain water ſtrongly impregnated with nitrous vapour. But the moment that abſorption begins, the dilute liquor of the firſt bottle is poured into the receiver, which makes it impoſſible to collect any concentrated acid, unleſs the operator is on the watch to looſen the luting between the retort and receiver the moment he perceives the liquor to riſe in the bent tube between the receiver and the firſt bottle. To remedy this defect ſeveral contrivances have been adopted. The inventor, Mr. Woulfe, who was fully aware of it, employed an intermediate veſſel between the receiver and the firſt water-bottle which was left empty, and into which the bent tube from the receiver was immerſed only to a ſhort depth, in conſequence of which when the abſorption took place the liquor from the firſt bottle was poured into this intermediate bottle and went no further. This contrivance is very uſeful where only a ſingle water-bottle is employed, but where more than one is uſed, it is obvious that the liquors contained in them muſt mingle, though they all keep ſeparate from the contents of the receiver; for when any of the liquor of the firſt bottle paſſes into the intermediate bottle, an equivalent portion of the ſecond muſt pour into the firſt bottle, of the third, into the ſecond, and ſo on. Another contrivance (and which is now generally adopted) is to prevent the abſorption altogether by letting in the external air to fill the partial vacuum. This is done either by inſerting ſtraight capillary tubes into the different veſſels, or by a curved tube of particular conſtruction invented by Welter, and called *Welter's Tubes*, or *Tubes of Safety*. A ſingle example of the ſtraight tubes is ſhewn in Pl. IV. Fig. 58. *a* is a bottle with three openings, half filled with water, which receives the gas or vapour from the preceding bottle, or from the receiver; the exceſs of which after paſſing through the water of *a* paſſes by the tube *d* into the bottle *e*, and which is only looſely ſtopped; *c* is an upright glaſs tube with a very narrow bore which juſt dips into the water of *a*. Conſequently, when an abſorption takes place in the receiver and water is ſucked up by *b*, it immediately ſinks the level of fluid in *a* below the bottom of the tube *c*, which then gives the bottle *a* a free communication with the air, and prevents the liquor of *e* from paſſing into it. This plan of upright tubes may be adopted for every bottle of the apparatus, and it is convenient from its ſimplicity, and any perſon may fit this apparatus for himſelf ſimply by cutting a piece of glaſs tube of the proper length, running it through a perforated cork, and luting all the joinings. It has however the great inconvenience that it is inapplicable to the receiver itſelf (which is preciſely the place where it is moſt requiſite to prevent the abſorption) as this veſſel is quite empty at firſt, and the quantity of liquid is conſtantly increaſing; and indeed the increaſing bulk of the fluid in the bottles is an objection to this method, as the end of the tube becomes progreſſively lower beneath the level of the fluid, and may eaſily be too low to act properly.

The *Tube of Safety*. Fig. 60. is a ſingle glaſs

tube bent as represented, and with a bulb blown in that part of the tube that lies between the upper and lower flexure. It has also a small funnel at the top, which, however, is not very essential. This tube is sometimes employed as a stopper to the tubulure of the retort, or to a separate opening in the receiver, and sometimes, as at *f* Fig. 59, it is cemented, by melting, into the tube passing from the receiver to the first bottle. Before using it, a little mercury is dropped down through the funnel, about sufficient to occupy the space of the tube that lies between the two lower flexures, which completely shuts up the access of the external air whilst the distillation is going on. But as soon as any vacuum is formed in the vessel to which it is attached, the mercury is forced up by the pressure of the atmosphere into the bulb, and not being in sufficient quantity to fill it, the external air passes by it in this place, and rushes into the apparatus. This very ingenious contrivance unites every convenience, for it supplies air to the vacuum precisely in the place where absorption begins, and in fact it renders useless all other contrivance to prevent absorption in any distant part of the apparatus. The only objection to the Welter's tube is its great fragility, more especially when connected with a conducting tube as in Fig. 59, which when firmly stoppered or luted in its place is liable to snap with the least shake, and besides a great many are broken in the making and grinding even by skilful artists. The other parts of Fig. 59 are obvious by mere inspection. *a* is an iron stand generally furnished with three sliding rings of different diameter, one of which is here represented; *b* is a small Argand lamp, very convenient for chemical purposes, being flat and low; *c* is a tubulated retort; *d*, a tubulated receiver, standing on a convenient wooden tripod *e*; *f* is the conducting tube with the Welter's tube affixed to it. The receiver *d* is left empty in the beginning of the distillation, and the vapour which does not condense there passes through *f* into the bottle *g*, and through *h* into the bottle *i*. To make the apparatus complete for experiments of research, a bent tube may be fastened in the lateral opening of *i*, conducting to a pneumatic trough.

Fig. 57 is a small apparatus nearly similar to one that has been lately suggested, of a series of Woulfe bottles without luting, in which the several parts have considerable play, so as to avoid any stress on the thin brittle tubes of which it is composed. Only a single specimen of the principle acted on is here introduced, which is in the vessel *d*. *a* is a matrass standing on one of the rings of an iron stand; *b* is a bent tube, one leg of which is cemented into the cork of *a*, the other passes down into the short jar *d*, through a much wider glass tube *c*. The lower end of *b* should be a little curved, so that any bubble of gas passing out of it may clear the edge of the tube *c* and pass up into the jar *d*, and both *b* and *c* dip a little way below the level of the liquor in *d*. The gas then passes out through *e* into the bottle *f* and so on, which may also be furnished with a wide tube similar to *c*, through which the lower part of *e* may pass. In all the common Woulfe's apparatus there is a perpetual risk of breaking the thin conducting tubes from the circumstance of having both of their lower extremities tightly fastened down either by lutes or by grinding, which gives a great stress to the middle of the tube unless the bottles remain perfectly upright, and exactly at the proper distance from each other. Whereas in this apparatus only one end of the conducting tube is fixed, and the other moves at ease within the larger tube that serves as its case, and any part of it may be instantly withdrawn and put on again without deranging the rest. The larger tube in this case also serves to prevent absorption as the tube *e* in Fig. 58.

Thus, for example, if it is wished to make liquid oxymuriatic acid by this apparatus, put the manganese and other materials in the matrass *a*, and a small quantity of water in *d* and fill *f* two-thirds full. The oxymuriatic gas passes along *b* into the small jar *d* where the common muriatic acid which it contains is detained by the small quantity of water in *d*, and the rest of the gas issues out through *e*, and goes to impregnate the water in *f*. If the materials in the matrass *a* are not sufficient, it may be drawn away by lifting out the tube *b*, and the vessel returned to its place without moving any other part of the apparatus. It should be observed, that wherever there is an open tube communicating with the bottles as at *c*, the greater pressure produced in the vessel by the influx of gas, and the resistance of the water into which the conducting tube *e* immerges, will cause the liquor in *d* to rise in the open tube *c*, and it will overflow, unless care is taken to proportion the height of the open tube to the pressure which it is to counteract.

Another variety of Woulfe's apparatus is given in Pl. III. Fig. 42. in which the absorption is prevented by a glass valve instead of a tube of safety. The construction of this valve

is the same as that of Nooth's apparatus, which has been already explained, and is given separately in Fig. 45. *a* (Fig. 42.) is the retort; *b* the receiver; *c* the glass valve; *d* an upper vessel into which is put the liquor to be saturated by the passage of the gas, and the residue passes on to *e*, *f*, *g*, *h*, *i*, as represented. The same apparatus may be used with equal convenience by removing the tube *e* and further part of the apparatus, and substituting the bottles *a* and *b*, Fig. 44, for which purpose the lower part of *a* is ground to fit the vessel *d*, Fig. 42. The mode of bending the tube *g* is shewn in Fig. 43. It is first ground to fit each bottle, then held over a large lamp, and bent above each ground part, after which another flexure is made in the middle; and the exact curve of the last is fitted by fixing the tube in the bottles, and softening it by a lamp, by which it precisely accommodates itself to its situation.

APPENDIX, No. II.

CONTAINING

TABLES OF WEIGHTS AND MEASURES—English and Foreign;
OF CHEMICAL INSTRUMENTS;
OF THE COMPOSITION OF ACIDS AND SALTS;
AND OF CHEMICAL AFFINITIES.

CONTENTS OF APPENDIX II.

APPENDIX, No. II.

OF ENGLISH WEIGHTS AND MEASURES.

THE weights and measures required by the chemiſt are few and ſimple, but they ſhould be accurate, and their relative values well defined.

For the meaſure of weight, the Troy pound of 12 ounces, or 5760 grains, is the integer almoſt always preferred, being that which admits of a minuter ſubdiviſion, and whoſe correſpondences with meaſures of capacity are more accurately defined; though there are ſtill ſome ſlight differences in this reſpect which it were to be wiſhed were removed by authority. The ſubdiviſions of the Troy ounce employed by chemiſts are ſometimes thoſe of Apothecaries weight, that is, the ounce into 8 drams, the dram into 3 ſcruples, and the ſcruple into 20 grains, or more commonly, ſimply into drams and grains; or ſometimes the ounce is divided into 20 pennyweights, and the pennyweight into 24 grains. Often the grain is the only integer employed, and ſets of weights are uſed of the different hundreds, tens, and units. The averdupois pound is however ſometimes adopted, being the ſtandard of moſt things bought and ſold in common life. It is equal to 7000 grains Troy, and is divided into 16 ounces, and the ounce legally into 16 drams, but the latter diviſion is never uſed by chemiſts, being liable to be miſtaken for the Troy dram, which weighs more than twice as much.

For meaſures of capacity, chemiſts employ both the *ounce meaſure* (or bulk occupied by the ounce, or any proportion of it, of diſtilled water at 60°) and the *cubic inch*. For larger quantities both the *Wine Pint* of 28.875 cubic inches, and the *Ale Pint*, of 35.25 cubic inches are uſed. Two pints make a *Quart*, and four quarts make a *Gallon*.

The correſpondence between meaſures of weight and capacity is found by the weight of a cubic inch of water. In this however a ſlight difference exiſts, in authorities apparently equally worthy of confidence, which depends partly on the extreme difficulty of conſtructing inſtruments of perfect accuracy, and partly on ſome ſlight diſcrepancy between the ſtandards themſelves. The extent of this difference is about half a grain in 253. We have adopted in the following Tables the eſtimations given by Sir G. Shuckburgh Evelyn, in the 88th vol. of the Philoſophical Tranſactions, corrected in a ſubſequent paper by Mr. Fletcher, in the 4th vol. of the Philoſophical Journal. On this calculation the cubic inch of diſtilled water at 60°. therm. and 29.5 bar. weighs 252.506 grains Troy.

Hence we have the following equations.

			Cubic inch.		
1 ounce Troy of water at 60° occupies - - - - - -			1.900945		
	grs. Troy.		*lb. Troy.*		*lb. Averdu.*
1 Wine pint of water weighs - - - -	7291.11075	=	1.26581783	=	1.04158725
	grs. Troy.		*lb. Troy.*		*lb. Averdu.*
1 Ale Pint of water weighs - - -	8900.8365	=	1.545284	=	1.271548
	Wine pint.		*Ale pint.*		
1 lb. Troy of water occupies - - - -	.7900031	=	.6471302		
	Wine pint.		*Ale pint.*		
1 lb. Averdupois of water occupies -	.960073	=	.7864429		

We may here notice the very common error of estimating a wine pint of water to be equal to 16 ounces Troy, since it wants as much as 389 grs. of 16 ounces, when the cubic inch is estimated at 252.506 grs. and 375 grs. when the cubic inch is reckoned at 253 grs. which is the highest estimation. Nevertheless as several measuring vessels are thus graduated, and as the adoption of this standard would be extremely convenient, this measurement may be often usefully employed for moderate quantities; but the chemist should then express that he uses the pint of 16 ounces Troy.

TABLE

For converting Cubic Inches of Water (at 60 Therm. and 29.5. Bar.) into their equivalents in Troy weight.

Cub. Inch of Water		*Troy grs.*	*oz.*	*dram*	*grs.*
1.	weighs	252.506 =	0	4	12.506
2.		505.012 =	1	0	25.012
3.		757.518 =	1	4	37.518
4.		1010.024 =	2	0	50.024
5.		1262.530 =	2	5	2.530
6.		1515.036 =	3	1	15.036
7.		1767.542 =	3	5	27.542
8.		2020.048 =	4	1	40.048
9.		2272.554 =	4	5	52.554
1728.	(1 cub. foot)	———	909	0	10.368

TABLE

For converting Troy grains, drams, ounces, and pounds of Water into their equivalent Cubic Inches.

Grain	*Cubic Inch*
1. =	.00396
2. =	.00792
3. =	.01188
4. =	.01584
5. =	.01980
6. =	.02376
7. =	.02772
8. =	.03168
9. =	.03564

Dram	*Cubic Inch*
1. =	.237618
2. =	.475236
3. =	.712854
4. =	.950472
5. =	1.188090
6. =	1.425708
7. =	1.663326

Ounce	*Cubic Inch*
1. =	1.900945
2. =	3.801890
3. =	5.702835
4. =	7.603780
5. =	9.504725
6. =	11.405670
7. =	13.306615
8. =	15.207560
9. =	17.108505
10. =	19.009450
11. =	20.910395

Pound	*Cubic Inch*
1 =	22.81134
2 =	45.62268
3 =	68.43402
4 =	91.24536
5 =	114.05670
6 =	136.86804
7 =	159.67938
8 =	182.49072
9 =	205.30206

TABLE

For converting Wine Pints of Water into their equivalent Troy and Averdupois Pounds.

Wine Pints		lbs. Troy		lbs.		oz.		dr.		grs.		lbs. averdup.
1.	=	1.26581783	=	1	:	3	:	1	:	31.1	=	1.04158725
2.	=	2.53163566	=	2	:	6	:	3	:	2.2	=	2.08317450
3.	=	3.79745349	=	3	:	9	:	4	:	33.3	=	3.12476175
4.	=	5.06327132	=	5	:	0	:	6	:	4.4	=	4.16634900
5.	=	6.32908915	=	6	:	3	:	7	:	35.5	=	5.20793625
6.	=	7.59490698	=	7	:	7	:	1	:	6.6	=	6.24952350
7.	=	8.86072481	=	8	:	10	:	2	:	37.7	=	7.29111075
8.	=	10.12654264	=	10	:	1	:	4	:	8.8	=	8.33269800
9.	=	11.39236047	=	11	:	4	:	5	:	39.9	=	9.37428525

TABLE

For converting Troy Pounds of Water into their equivalent Wine Pints.

Troy Pound		Wine Pints	Troy Pound		Wine Pints
1.	=	0.7900031	6.	=	4.7400186
2.	=	1.5800062	7.	=	5.5300217
3.	=	2.3700093	8.	=	6.3200248
4.	=	3.1600124	9.	=	7.1100279
5.	=	3.9500155			

TABLE

For converting Troy Pounds into their equivalent Averdupois Pounds.

lbs. Troy		lbs. Averdups.	lbs. Troy		lbs. Averdups.
1.	=	0.822857714	6.	=	4.937142857
2.	=	1.645714285	7.	=	5.760000000
3.	=	2.468571428	8.	=	6.582857142
4.	=	3.291428571	9.	=	7.405714285
5.	=	4.114285714			

TABLE

For converting Averdupois Pounds into their equivalent Troy Pounds.

lbs. Averd.		lbs. Troy	lbs. Averd.		lbs. Troy
1.	=	1.215277	6.	=	7.291666
2.	=	2.430555	7.	=	8.506944
3.	=	3.645833	8.	=	9.722222
4.	=	4.861111	9.	=	10.937500
5.	=	6.076388			

TABLE

For converting Averdupois Ounces into Decimals of the Averdupois Pound.

Oz. Av.		*lbs. Av.*	*Oz. Av.*		*lbs. Av.*
.25	=	.015625	8.00	=	.5000
.50	=	.03125	9.00	=	.5625
1.00	=	.0625	10.00	=	.6250
2.00	=	.1250	11.00	=	.6875
3.00	=	.1875	12.00	=	.7500
4.00	=	.2500	13.00	=	.8125
5.00	=	.3125	14.00	=	.8750
6.00	=	.3750	15.00	=	.9375
7.00	=	.4375			

TABLE

For converting Decimals of the Averdupois Pound into Averdupois Ounces and Decimals.

lbs. Av.		*oz. Av.*	*lbs. Av.*	*oz. Av.*
.1	=	1.6	.01	.16
.2	=	3.2	.02	.32
.3	=	4.8	.03	.48
.4	=	6.4	.04	.64
.5	=	8.0	.05	.80
.6	=	9.6	.06	.96
.7	=	11.2	.07	1.12
.8	=	12.8	.08	1.28
.9	=	14.4	0.9	1.44

TABLE

For converting Ounces, Drams and Grains Troy into Decimals of the Troy Pound.

Grain		*lbs. Troy*	*Dram*		*lbs. Troy*	*Oz.*		*lbs. Troy*
1.	=	.000173611	1.	=	.0104166	1.	=	.0833
2.	=	.000347222	2.	=	.0208333	2.	=	.1666
3.	=	.000520833	3.	=	0312500	3	=	.2500
4.	=	.000694444	4.	=	.0416666	4	=	.3333
5.	=	.000868055	5.	=	.0520833	5	=	.4166
6.	=	.001041666	6.	=	.0625000	6	=	.5000
7.	=	.001215277	7.	=	.0729166	7	=	.5833
8.	=	.001388888				8	=	.6666
9.	=	.001562500				9	=	.7500
						10	=	.8333
						11	=	.9166

TABLE.

For converting Decimals of the Troy pound into Troy Ounces, Drams, and Grains.

lb.		oz.	dr.	grains	lb.		oz.	dr.	grains	lbs.		grains.
.1	=	1 :	1 :	36	.01	=	0 :	0 :	57.6	.001	=	5.76
.2	=	2 :	3 :	12	.02	=	0 :	1 :	55.2	.002	=	11.32
.3	=	3 :	4 :	48	.03	=	0 :	2 :	52.8	.003	=	17.28
.4	=	4 :	6 :	24	.04	=	0 :	3 :	50.4	.004	=	23.04
.5	=	6 :	0 :	0	.05	=	0 :	4 :	48.0	.005	=	28.80
.6	=	7 :	1 :	36	.06	=	0 :	5 :	45.6	.006	=	34.56
.7	=	8 :	3 :	12	.07	=	0 :	6 :	43.2	.007	=	40.32
.8		9 :	4 :	48	.08	=	0 :	7 :	40.8	.008	=	46.08
.9		10 :	6 :	24	.09	=	0 :	8 :	38.4	.009	=	51.84

FRENCH WEIGHTS AND MEASURES.

THE numerous and valuable researches of French authors in every branch of chemistry require a knowledge in the reader of the weights and measures commonly employed by them; which is more particularly necessary as the denominations common to several measures in both countries express very different quantities both absolutely and relatively, which sometimes leads to very serious mistakes. Thus the French *pinte* is equal to nearly two English pints: the *gros* or eighth of an ounce contains 72 grains, whereas our *dram*, which is usually reckoned as its equivalent, contains only 60 grains: the French grain is of less absolute weight than the English grain, but the French inch is longer, and hence the same proportion does not hold in the two countries between the measures of weight and capacity.

The standards of weight and measure were totally changed in France about the year 1794, nearly at the time that similar changes were introduced in the divisions of the year, but though the notation of time has now returned to its ancient course, the system of weights and measures appear still to keep their ground, and are actually adopted in all chemical writings. It is highly necessary, however, to give the old, as well as the new system of mensuration, as the most numerous, and as yet the most important, researches, such as those of Lavoisier, Beaumé, Macquer, &c. were made before the present system was adopted.

We possess very accurate standards of comparison between the French weights and measures and our own, the old French having been carefully compared with the English standards by a commission from the Royal Societies of each country in the year 1752; and the modern French *metre* having been compared with equal accuracy with the English inch by Profr. Pictet in 1801.

The old French weights and measures are the following:

The pound (*poids de marc*) contains 9216 grains, and is divided into 16 ounces, the ounce into 8 gros, and the gros into 72 grains: or as follows:

grains					
24 =	1 denier				
72 =	3 =	1 gros			
576 =	24 =	8 =	1 ounce		
4608 =	192 =	64 =	8 =	1 marc	
9216 =	384 =	128 =	16 =	2 =	pound

				lb. troy
The French pound is equal to	7561.	troy grains	=	1.31268
				oz. troy
The French ounce is =	472.5625	d°	=	.984504
				dram
The French gros =	59.0703125	d°	=	.984504
The French grain =	0.820421	d°		
The troy pound is equal to	7021.	French grains		
The averdupois pound =	8538.	d°		

In the reduction of the French into English measure, the following Table will assist.

French grains		*Troy grains*
1.	=	0.820421
2.	=	1.640842
3.	=	2.461263
4.	=	3.281684
5.	=	4.102105
6.	=	4.922526
7.	=	5.742947
8.	=	6.563368
9.	=	7.383789
10.	=	8.20421
20.	=	16.40842
30.	=	24.61263
40.	=	32.81684
50.	=	41.02105
60.	=	49.22526
70.	=	57.42947
72.	=	59.070312

gros		*drams*		*grs.*
1	=	0	:	59.07
2	=	1	:	58.14
3	=	2	:	57.21
4	=	3	:	56.28
5	=	4	:	55.35
6	=	5	:	54.42
7	=	6	:	53.49

French oz.		*Troy oz.*		*drams*		*grains*
1.	=	0	:	7	:	52.56
2.	=	1	:	7	:	45.12
3.	=	2	:	7	:	37.68
4.	=	3	:	7	:	30.24
5.	=	4	:	7	:	22.80
6.	=	5	:	7	:	15.36
7.	=	6	:	7	:	7.92
8.	=	7	:	7	:	0.48
9.	=	8	:	6	:	53.04
10.	=	9	:	6	:	45.60
11.	=	10	:	6	:	38.16
12.	=	11	:	6	:	30.72
13.	=	12	:	6	:	23.28
14.	=	13	:	6	:	15.84
15.	=	14	:	6	:	8.40
Pounds						
1.	=	15	:	6	:	1
2.	=	31	:	4	:	2
3.	=	47	:	2	:	3
4.	=	63	:	0	:	4
5.	=	78	:	6	:	5
6.	=	94	:	4	:	6
7.	=	110	:	2	:	7
8.	=	126	:	0	:	8
9.	=	141	:	6	:	9

The French toise (which corresponds with our fathom) contains 6 feet, the foot is divided into 12 inches, and the inch into 12 lines.

The French half-toise was found by the authentic measurement of the French academy to be equal to 38.355 English inches; and hence

		English foot
The French foot is equal to 12.785 English inches, or to		1.0654167
		French foot
The English foot =	11.2632 French inches, or to	.9386

The sub-divisions of the foot being the same in both countries, their relative proportions are also the same; so that the French inch = 1.0654167 English inches;—and the English inch = .9386 French inches.

	feet	*inch*	*lines*		*Eng. inches*
The old French ell (*Aune*) =	3 :	7 :	10.5	French, =	46.69

French feet		English inches
1.	=	12.785
2.	=	25.570
3.	=	38.355
4.	=	51.140
5.	=	63.925
6.	=	76.710
7.	=	89.495
8.	=	102.280
9.	=	115.065
10.	=	127.850

Fr. feet or inches		Eng. feet or inches
1	=	1.0654+
2	=	2.1308
3	=	3.1962
4	=	4.2616
5	=	5.3270
6	=	6.3925
7	=	7.4579
8	=	8.5233
9	=	9.5887
10	=	10.6541
11	=	11.7195
12	=	12.7850

The French square foot or inch	=	1.13510	English square foot or inch
The English square foot or inch	=	.88126	French square foot or inch
The French cubic foot or inch	=	1.209367	English cubic foot or inch
The English cubic foot or inch	=	.8268784	French cubic foot or inch

French cube foot or inch		Eng. cube foot or inch
1	=	1.2093+
2	=	2.4187
3	=	3.6281
4	=	4.8374
5	=	6.0468
6	=	7.2562
7	=	8.4655
8	=	9.6749
9	=	10.8842
10	=	12.0936

When one French cubic inch weighs 1 grain French, or contains 1 gr. of any other ſubſtance, 1 Engliſh cubic inch of the ſame weighs or contains .67839 Eng. grain.

For meaſures of capacity the old French was (as in this country) different for dry meaſure and for liquids. The common integer for moderate quantities of liquids was the *Pinte*, which is a little more than a quart Engliſh wine meaſure. The *Chopine* is half the *Pinte*, and the *Poiſon* is a quarter of the Chopine. For larger meaſures, 8 *Pintes* make a *Septier* or *Velte* and 36 *Veltes* make a *Muid de Vin* Paris meaſure, for in the provinces both the diviſions and their value were different. There appears alſo to have been, even in Paris, preciſely the ſame kind of variation in the eſtimation of the *Pinte* as obtains in this country with the wine pint. The French *Pinte* appears to have been legally equivalent to 48 Fr. cubic inches, and then was exactly $\frac{1}{288}$ of the *Muid*, which was 8 cubic feet. But Beaumé, and probably the other apothecaries of Paris (a body of men abounding in excellent and eminent chemiſts) make the *Pinte* equal to 32 French ounces of water at the freezing point. The reſpective valuations of the Pinte will therefore be as follows:

	oz.		lbs. troy		En. cub. inch		Fr. cub. in:		Eng. wine pint
The pinte of	32	=	2.62536	=	59.888	=	49.52	=	2.07404
	cub. inch		Eng. cub. inch						
The pinte of	48	=	58.0489	=	. . .				2.01035

difference .06369, equal to about 7 drams, 40 grs. Troy of water.

This difference of nearly an ounce in a quart is ſufficiently great to be often felt in the compariſon of experiments. The Pinte of 48 Fr. cubic inches appears for another reaſon to be the legal ſtandard, ſince it is thus given in the compariſon of the old with the new French weights. The Pinte is there ſtated to be equal to .9512 of a *Litre*, which is equal to 2.01038 Engliſh wine pints.

For dry meaſure the French uſed the *Litron*, *Boiſſeau*, *Minot*, *Mine*, and *Setier de Bled*. The *Litron* is 36 Fr. cubic inches, equal to 1.4652 Eng. wine pint. The *Minot* of 1728 Fr. cub. inch is equal to 1.0099 Wincheſter buſhel of 2110.4 Eng. cub. inch.

The following are the ſubdiviſions of the old French wine and corn meaſure.

Poiſon				
4 =	1 Chopine			
8 =	2 =	1 Pinte		
64 =	16 =	8 =	1 Septier or velte	
2304 =	576 =	288 =	36 =	1 Muid de vin

Litron					
4 =	1 Quart				
16 =	4 =	1 Boiſſeau			
48 =	12 =	3 =	1 Minot		
96 =	24 =	6 =	2 =	1 Mine	
192 =	48 =	12 =	4 =	2 =	1 Setier de Bled

A totally new ſyſtem of weights and meaſures has been introduced into the French empire, and is that in which moſt of the expreſſions of quantities in chemical experiments are now made. It is therefore neceſſary in this place to give their correſponding quantities in Engliſh meaſures.

The new French metrical ſyſtem is founded on a ſingle ſtandard of length which is called the Metre, and is the ten millionth part of the arc of the meridian which extends from the Equator to the Pole, as determined by the actual meaſurement of a tenth of this arc, between Dunkirk and Barcelona by ſeveral eminent French aſtronomers. The metre is equal to 36.9413 French inches, which is equal to 39.38272 Engliſh inches, the ſtandards of each being at the temperature of melting ice or 32° Fahr. But as the ſtandards in this country are always referred to the temperature of 60° or 62°, (and the latter is now preferred) the expanſion of braſs (which is the material of which the ſtandards are made) from 32° to 62° muſt always be taken into account; for it is obvious that if the Engliſh ſtandard is at 62° and the French at 32°, the latter will meaſure a leſs quantity of the former than if both were at 32°. The number 39.38272 therefore, which is the equivalent to the French metre when both are at 32°, muſt be diminiſhed in the proportion in which braſs expands 30 degrees, which is eſtimated by Dr. Young, from Bordas experiments, to make the equivalent to the metre to be 39.371 Engliſh inches, the ſtandard of the metre being at 32°, and that of the Engliſh inch at 62°.

All the new French meaſures increaſe and decreaſe in decimal proportion, a diſtinctive prefix being put to the term by which the integer is called. Theſe prefixes are Deca-, Hecto-, Kilo-, and Myria-, (taken from the Greek numerals) to expreſs the *multiplication* of the integer by 10, 100, 1000, and 10000 reſpectively; and Deci-, Centi-, and Milli-, (from the Latin numerals) to expreſs the *diviſion* of the integer by 10, 100, or 1000. Or according to the following ſcale, taking the metre as the integer.

		Metres			*Metres*
1 Myriametre	=	10000.	1 Metre	=	1.
1 Kilometre	=	1000.	1 Decimetre	=	0.1
1 Hectometre	=	100.	1 Centimetre	=	0.01
1 Decametre	=	10.	1 Millimetre	=	0.001

The metre is the integer of the meaſure of length, and from it all the meaſures of ſurface, capacity and weight, are deduced in the following way.

For ſquare dimenſions the metre or its parts ſquared are employed. When uſed for meaſuring land the term *Are* is adopted, which is a decametre ſquared. A *Hectare*, or 100 *Ares*, are about equivalent to 2 Engliſh acres.

For the integer of the meaſure of capacity both wet and dry, the decimetre cubed is employed, and is called the *Litre*. It is more than a third larger than the old French Litron, and is equal to 2⅛ Engliſh wine pints.

The cubic metre is alſo called a *Stere*, but is only uſed for meaſuring fire wood, to be ſubſtituted for the old French *Corde de Bois*.

For the integer of the meaſure of weight, the weight of a cubic centimetre of diſtilled water at 32° has been adopted. This is called a *Gramme*, and is equivalent to about 15½ Engliſh grains.

Of these measures the *Metre, Litre,* and *Gramme,* are almost the only integers that the chemical reader will ever meet with, and certainly their uniformity and exact ratio to each other, and decimal progression, render the comparison of them with our own measures extremely easy.

The following are the correspondences between these and English measures.

The METRE = 39.371 English inches.

The square Metre = 1550.075641 English square inches.

The square Decimetre = 15.50075 English square inches.

The Cubic Metre = 61028.028 English cubic inches = 35 *cube feet.* : 548.028 *cub. inch.*

The Cubic Decimetre, the same as the Litre.

THE LITRE, equal to the bulk of Kilogramme of water = 61.028 *English cubic inches.*

THE GRAMME, or weight of a cubic Centimetre of water = 15.44402 *Troy grains.*

The following Tables will assist the Reader.

Metre.		*Eng. feet.*		*Inches.*	*Decimetre.*		*Eng. Inches.*
1.	=	3	:	3.371	1.	=	3.9371
2	=	6	:	6.742	2.	=	7.8742
3	=	9	:	10.113	3.	=	11.8113
4	=	13	:	1.484	4.	=	15.7484
5	=	16	:	4.855	5.	=	19.6855
6	=	19	:	8.226	6.	=	23.6226
7	=	22	:	11.597	7.	=	27.5597
8	=	26	:	2.968	8.	=	31.4968
9	=	29	:	6.339	9.	=	35.4339

Litre		*En. cub. inch*		*Ale pints*		*Wine pints*		*Oz. troy of water*
1.	=	61.028	=	1.7313	=	2.11353	=	32.104
2.	=	122.056	=	3.4626	=	4.22706	=	64.208
3.	=	183.084	=	5.1939	=	6.34059	=	96.312
4.	=	244.112	=	6.9252	=	8.45412	=	128.416
5.	=	305.140	=	8.6565	=	10.56765	=	160.520
6.	=	366.168	=	10.3878	=	12.68118	=	192.624
7	=	427 196	=	12.1191	=	14.79471	=	224.728
8	=	488.224	=	13.8504	=	16.90824	=	256.832
9	=	549.252	=	15.5817	=	19.02177	=	288.936

Gramme		*Troy grains*	*Decagramme*		*Troy dram*		*grs.*	*Hectogramme*		*Troy oz.*		*Averd. oz.*
1.	=	15.444	1.	=	2	:	34.44	1.	=	3.2175	=	3.5279
2.	=	30.888	2.	=	5	:	8.88	2.	=	6.4350	=	7.0558
3.	=	46.332	3.	=	7	:	43.32	3.	=	9.6525	=	10.5837
4	=	61.776	4.	=	10	:	17.76	4.	=	12.8700	=	14.1116
5	=	77.220	5.	=	12	:	52.20	5.	=	16.0875	=	17.6395
6	=	92.664	6.	=	15	:	26.64	6.	=	19.3050	=	21.1674
7	=	108.108	7.	=	18	:	1.08	7.	=	22.5295	=	24.6953
8	=	123.552	8.	=	20	:	35.52	8.	=	25.7400	=	28.2232
9	=	138.996	9.	=	23	:	9.96	9.	=	28.9575	=	31.7511

The decimal progression of all the French weights and measures renders it only necessary to change the decimal point in order to convert one into the equivalent of any other, of the same species and numerically the same, but of a different denomination. Thus as 9 litres are equal to 15.5817 ale pints, 9 hectolitres will be equal to 1558.17 ale pints; and so of the rest.

GERMAN WEIGHTS AND MEASURES.

A VAST variety of weights and meaſures are in local uſe in Germany, as ſlight differences exiſt between the *mark*, *ell*, &c. of almoſt every ſtate. There appears, however, from the accurate account given by Gren (in his Syſtem. Handbuch der Chemie, Vol. 1.) to be two kinds of weight to which all thoſe employed in Germany may be referred, and which are ſufficient for our preſent purpoſe.

The ancient and moſt authentic ſtandard of weight is the

Cologne Mark or *Mark of Charlemagne* with its diviſions. The mark is the higheſt integer uſed in this ſtandard which was intended for gold and ſilver, but it is alſo conſidered as half the Cologne pound. The *mark* contains 8 ounces, the *ounce* 2 loths, the *loth* 4 quentchens or drams, and the *quentchen* 1 pfenning, pennyweight, or denier. Beſides this, the *pfenning* is ſubdivided into 256 *Recht-pfenning theil*, or ſtandard parts, which laſt diviſion, however, is only hypothetical, but is extremely uſeful for compariſon; for as the pfenning is itſelf the 256th part of the mark, the latter contains 65536 ſtandard parts, which is a ſufficiently minute diviſion for all actual calculations. The Cologne Mark therefore is thus divided:

Standard parts										
256	=	1 Pfenning								
1024	=	4	=	1 Quentchen						
4096	=	16	=	4	=	1 Loth				
8192	=	32	=	8	=	2	=	1 Ounce		
65536	=	256	=	64	=	16	=	8	=	1 Mark

Alſo two marks make a pound. The Pfenning is further ſubdivided either into 2 *Heller*, or into 17 *Eſchen*, or into 9 *As*.

The *Grain* weight therefore does not enter into this diviſion of the Cologne Mark, but in the diviſion for weighing gold and ſilver it is uſed, as will be mentioned.

The other ſet of weights uſed commonly in Germany is the *Nuremburg Medicinal Weight*, the integer or pound of which is divided preciſely the ſame as the apothecaries' diviſion of the Engliſh pound Troy; that is to ſay, the pound into 12 ounces, the ounce into 8 drams, the dram into 3 ſcruples, and the ſcruple into 20 grains. Neither the pound nor ounce nor dram of the Nuremburg weight are the ſame as the pound, ounce, and quentchen of the Cologne weight, the Nuremburg pound being = 100423.5 ſtandard parts — and the ounce = 8368.625 St. Pts. For commerce and common uſe the Nuremburg pound is increaſed to 16 ounces = 133898 St. Pts.

The Nuremburg medicinal pound of 12 ounces appears to be the ſtandard for apothecaries' weight all over Germany, and therefore is probably that which is more commonly uſed by chemiſts. Hence, when we meet with the term pound, ounce, dram, and grains, in German chemical authors, we may generally conclude that it is the Nuremburg medicinal weight, unleſs otherwiſe ſpecified.

But the Cologne Mark weight is employed univerſally for aſſaying gold and ſilver, and therefore is alſo of very frequent occurrence.

The Engliſh Troy pound is given by Gren as equal to 104688 St. Pts. of the Cologne Mark, whence the Nuremburg pound, ounce, dram, ſcruple or grain = .959266 Engliſh Troy pound, ounce, dram, &c. reſpectively: or by the following table.

Nuremberg		*Eng. troy*	*Nuremberg*		*Eng. troy*
1	=	0.95926	6	=	5.75560
2	=	1.91853	7	=	6.71486
3	=	2.87780	8	=	7.67413
4	=	3.83706	9	=	8.63339
5	=	4.79633			

The Cologne ounce is = 8192 standard pts. and the Troy ounce is = 8724 st. pts. whence the Cologne ounce, and eighth of an ounce (or quentchen) is = .939018 Troy ounce or dram respectively: and the Cologne mark is = 7.512144 Troy ounces; or by the following table:

Cologne oz. or Quentchen		*Troy oz. or dram*	*Cologne oz. or Quentchen*		*Troy oz. or dram*
1	=	.939	6	=	5.634
2	=	1.878	7	=	6.573
3	=	2.817	8	=	7.512
4	=	3.756	9	=	8.451
5	=	4.695			

When gold and silver are weighed in Germany by the Cologne mark, it has a totally different subdivision from the common ounce, quentchen, and pfenning.

For gold, the mark is divided into 24 carats, and the carats into 12 grains. The *Carat* therefore, where it is a real weight, is equal to 150.242 Troy grains, and the *Grain*, or 288th part of the mark is equal to 12.52 Troy grains.

For silver, the mark is divided, as usual, into 16 *Loths*, or half ounces, but the loth into 18 *Grains*. The grain is in this case also the 288th part of the mark. This circumstance of employing the term *grain* occasionally for a subdivision of the mark, and giving to it a value upwards of 13 times the Nuremburg grain should be carefully noted, as many errors may arise from it, particularly to the English reader.

The method of conducting the assay of gold and silver has been described under the article Assay, and it is there mentioned (p. 117) that the small piece of gold cut off the ingot to be assayed is called an *Assay mark*, and (like the real mark of gold) is divided into 24 carats, and each carat into 12 grains, by small sets of weights used for this purpose. The actual quantity of gold used for this purpose is half a pfenning, or $\frac{1}{512}$ of a real mark = 128 standard parts, or about 7 grains Troy. The assay grain is further divided into halves and quarters. The *Assay mark for Silver* is divided as the real mark for this metal, namely, into 16 loths, and each loth into 18 grains, and the grain into halves and quarters; and the real weight of the silver assay mark is twice that of gold, or one pfenning.

The German assayers and mineralogists have also the *Docimastic Centner*, which has generally the actual weight of one quentchen (equal to 56.34 grains Troy) but is subdivided into 100 docimastic pounds, each of which therefore is equivalent to about $\frac{1}{2}$ grain Troy.

The most common measure of length in Germany is the *Rhinland foot*, to which standard the foot, ell, &c of the different states is usually compared.

With regard to the length of this measure in English inches, the *Pied du Rhin* is said in Peuchet's Dict. de Commerce, to be = 11 inch. : 7 lines, of the old French *pied de roi*, which is = 12.341 English inches. Hence we have the following numbers, viz. 1 Rhinland foot = 12.341, English inches, and therefore 1 Rhinland inch = 1.02842 English inches, and 1 cubic inch Rhinland = 1.08769 English cubic inches, = 274.648 Troy grains of distilled water = 286.31. Nuremb. grains.

On the other hand, Klaproth in his analysis of the Carlsbad water, and in the other parts of his works, employs the cubic inch, which, he says, holds 290 of the true Nuremburg grains of distilled water, and which appears to be as common a standard of length among the German chemists as the Nuremburg is of weight. Now according to Gren, 290 Nuremb. grains, = 278.187 Troy grains, = 1.10169 English cubic inch. of water, and the cube root of 1.101700+ (which hardly differs from 1.101693) is = 1.032812. So that the inch used by Klaproth is probably the Rhinland inch, which by this estimation is = 1.032812 English inches, and by the former is = 1.02842, English inches, the difference being only about .0044.

We may therefore without danger of material error, consider the inch used by most of the German chemists (unless otherwise specified) as that which, when cubed, contains 290 Nuremburg grains of water, and as having the following proportions with the English.

Germ. feet or inches.		Eng. feet or inches.	Germ. cub. inch.		E. cub. inch.
1.	=	1.0328	1	=	1.1017
2.	=	2.0656	2	=	2.2034
3	=	3.0984	3	=	3.3051
4	=	4.1312	4	=	4.4068
5	=	5.1640	5	=	5.5085
6	=	6.1969	6	=	6.6102
7	=	7.2297	7	=	7.7119
8	=	8.2625	8	=	8.8136
9	=	9.2953	9	=	9.9153

When 1 German cubic inch weighs or contains 1 Nuremburg grain; 1 cubic inch English weighs or contains .8707 Troy grain.

TABLES RELATING TO THE THREE THERMOMETERS COMMONLY USED.

Under the article Thermometer in Appendix. I. we have mentioned that the thermometers commonly employed, are *Fahrenheit's*, in this country univerfally; *Reaumur's* on moft parts of the continent; and lately *Celfius's*, or the Swedifh thermometer, has been adopted in France under the name of the *Centigrade*. Both the zero and the divifions of each of thefe three differ. The following three tables will give the correfpondences of each thermometer for every degree of each from 212° of Fahr. the boiling point of water, to — 40, the freezing point of mercury.

Table for Fahrenheit's Thermometer.

Fahr.	*Reau.*	*Cent.*	*Fahr.*	*Reau.*	*Cent.*	*Fahr.*	*Reau.*	*Cent.*
212	80.00	100.00	170	61.33	76.66	128	42.66	53.33
211	79.55	99.44	169	60.88	76.11	127	42.22	52.77
210	79.11	98.88	168	60.44	75.55	126	41.77	52.22
209	78.66	98.33	167	60.00	75.00	125	41.33	51.66
208	78.22	97.77	166	59.55	74.44	124	40.88	51.11
207	77.77	97.22	165	59.11	73.88	123	40.44	50.55
206	77.33	96.66	164	58.66	73.33	122	40.00	50.00
205	76.88	96.11	163	58.22	72.77	121	39.55	49.44
204	76.44	95.55	162	57.77	72.22	120	39.11	48.88
203	76.00	95.00	161	57.33	71.66	119	38.66	48.33
202	75.55	94.44	160	56.88	71.11	118	38.22	48.77
201	75.11	93.88	159	56.44	70.55	117	37.77	47.22
200	74.66	93.33	158	56.00	70.00	116	37.33	46.66
199	74.22	92.77	157	55.55	69.44	115	36.88	46.11
198	73.77	92.22	156	55.11	68.88	114	36.44	45.55
197	73.33	91.66	155	54.66	68.33	113	36.00	45.00
196	72.88	91.11	154	54.22	67.77	112	35.55	44.44
195	72.44	90.55	153	53.77	67.22	111	35.11	43.88
194	72.00	90.00	152	53.33	66.66	110	34.66	43.33
193	71.55	89.44	151	52.88	66.11	109	34.22	42.77
192	71.11	88.88	150	52.44	65.55	108	33.77	42.22
191	70.66	88.33	149	52.00	65.00	107	33.33	41.66
190	70.22	87.77	148	51.55	64.44	106	32.88	41.11
189	69.77	87.22	147	51.11	63.88	105	32.44	40.45
188	69.33	86.66	146	50.66	63.33	104	32.00	40.00
187	68.88	86.11	145	50 22	62.77	103	31.55	39.44
186	68.44	85.55	144	49.77	62.22	102	31.11	38.88
185	68.00	85.00	143	49.33	61.66	101	30.66	38.33
184	67.55	84.44	142	48.88	61.11	100	30.22	37.77
183	67.11	83.88	141	48.44	60.55	99	29.77	37.22
182	66.66	83.33	140	48.00	60.00	98	29.33	36.66
181	66.22	82.77	139	47.55	59.44	97	28.88	36.11
180	65.77	82.22	138	47.11	58.88	96	28.44	35.55
179	65.33	81 66	137	46.66	58.33	95	28.00	35.00
178	64.88	81.11	136	46.22	57.77	94	27.55	34.44
177	64.44	80.55	135	45.77	57.22	93	27.11	33.88
176	64.00	80.00	134	45.33	56.66	92	26.66	33.33
175	63.55	79.44	133	44.88	56.11	91	26.22	32.77
174	63.11	78.88	132	44.55	55.55	90	25.77	32.22
173	62.66	78.33	131	44.00	55.00	89	25.33	31.66
172	62.22	77.77	130	43.55	54.44	88	24.88	31.11
171	61.77	77.22	129	43.11	53.88	87	24.44	30.55

Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.
86	24.00	30.00	43	4.88	6.11	0	-14.22	-17.77
85	23.55	29.44	42	4.44	5.55	-1	14.66	18.33
84	23.11	28.88	41	4.00	5.00	2	15.11	18.88
83	22.66	28.33	40	3.55	4.44	3	15.55	19.44
82	22.22	27.77	39	3.11	3.88	4	16.00	20.00
81	21.77	27.22	38	2.66	3.33	5	16.44	20.55
80	21.33	26.66	37	2.22	2.77	6	16.88	21.11
79	20.88	26.11	36	1.77	2.22	7	17.33	21.66
78	20.44	25.55	35	1.33	1.66	8	17.77	22.22
77	20.00	25.00	34	0.88	1.11	9	18.22	22.77
76	19.55	24.44	33	0.44	0.55	10	18.66	23.33
75	19.11	23.88	32	0.	0	11	19.11	23.88
74	18.66	23.33	31	-0.44	-0.55	12	19.55	24.44
73	18.22	22.77	30	0.88	1.11	13	20.00	25.00
72	17.77	22.22	29	1.33	1.66	14	20.44	25.55
71	17.33	21.66	28	1.77	2.22	15	20.88	26.11
70	16.88	21.11	27	2.22	2.77	16	21.33	26.66
69	16.44	20.55	26	2.66	3.33	17	21.77	27.22
68	16.00	20.00	25	3.11	3.88	18	22.22	27.77
67	15.55	19.44	24	3.55	4.44	19	22.66	28.33
66	15.11	18.88	23	4.00	5.00	20	23.11	28.88
65	14.66	18.33	22	4.44	5.55	21	23.55	29.44
64	14.22	17.77	21	4.88	6.11	22	24.00	30.00
63	13.77	17.22	20	5.33	6.66	23	24.44	30.55
62	13.33	16.66	19	5.77	7.22	24	24.88	31.11
61	12.88	16.11	18	6.22	7.77	25	25.33	31.66
60	12.44	15.55	17	6.66	8.33	26	25.77	32.22
59	12.00	15.00	16	7.11	8.88	27	26.22	32.77
58	11.55	14.44	15	7.55	9.44	28	26.66	33.33
57	11.11	13.88	14	8.00	10.00	29	27.11	33.88
56	10.66	13.33	13	8.44	10.55	30	27.55	34.44
55	10.22	12.77	12	8.88	11.11	31	28.00	35.00
54	9.77	12.22	11	9.33	11.66	32	28.44	35.55
53	9.33	11.66	10	9.77	12.22	33	28.88	36.11
52	8.88	11.11	9	10.22	12.77	34	29.33	36.66
51	8.44	10.55	8	10.66	13.33	35	29.77	37.22
50	8.00	10.00	7	11.11	13.88	36	30.22	37.77
49	7.55	9.44	6	11.55	14.44	37	30.66	38.33
48	7.11	8.88	5	12.00	15.00	38	31.11	38.88
47	6.66	8.33	4	12.44	15.55	39	31.55	39.44
46	6.22	7.77	3	12.88	16.11	40	32.00	40.00
45	5.77	7.22	2	13.33	16.66			
44	5.33	6.66	1	13.77	17.22			

Table for Reaumur's Thermometer.

Reau	Cent.	Fahr.	Reau	Cent.	Fahr.	Reau	Cent.	Fahr.
80	100.	212.	42	52.5	126.5	4	5.	41.
79	98.75	209.75	41	51.25	124.25	3	3.75	38.75
78	97.5	207.5	40	50.	122.	2	2.5	36.5
77	96.25	205.25	39	48.75	119.75	1	1.25	34.25
76	95.	203	38	47.5	117.5	0	0	32
75	93.75	200.75	37	46.25	115.25	−1	−1.25	29.75
74	92.5	198.5	36	45	113.	2	2.5	27.5
73	91.25	196.25	35	43.75	110.75	3	3.75	25.25
72	90	194.	34	42.5	108.5	4	5	23
71	88.75	191.75	33	41.25	106.25	5	6.25	20.75
70	87.5	189.5	32	40.	104	6	7.5	18.5
69	86.25	187.25	31	38.75	101.75	7	8.75	16.25
68	85	185.	30	37.5	99.5	8	10.	14.
67	83.75	182.75	29	36.25	97.25	9	11.25	11.75
66	82.5	180.5	28	35	95.	10	12.5	9.5
65	81.25	178.25	27	33.75	92.75	11	13.75	7.25
64	80	176.	26	32.5	90.5	12	15.	5.
63	78.75	173.75	25	31.25	88.25	13	16.25	2.75
62	77.5	171.5	24	30	86.	14	17.5	0.5
61	76.25	169.25	23	28.75	83.75	15	18.75	−1.75
60	75.	167.	22	27.5	81.5	16	20.	4.
59	73.75	164.75	21	26.25	79.25	17	21.25	6.25
58	72.5	162.5	20	25	77.	18	22.5	8.5
57	71.25	160.25	19	23.75	74.75	19	23.75	10.75
56	70.	158.	18	22.5	72.5	20	25.	13.
55	68.75	155.75	17	21.25	70.25	21	26.25	15.25
54	67.5	153.5	16	20	68	22	27.5	17.5
53	66.25	151.25	15	18.75	65.75	23	28.75	19.75
52	65.	149	14	17.5	63.5	24	30.	22.
51	63.75	146.75	13	16.25	61.25	25	31.25	24.25
50	62.5	144.5	12	15	59.	26	32.5	26.5
49	61.25	142.25	11	13.75	56.75	27	33.75	28.75
48	60.	140.	10	12.5	54.5	28	35	31
47	58.75	137.75	9	11.25	52.25	29	36.25	33.25
46	57.5	135.5	8	10	50	30	37.5	35.5
45	56.25	133.25	7	8.75	47.75	31	38.75	37.75
44	55	131.	6	7.5	45.5	32	40.	40.
43	53.75	128.75	5	6.25	43.25			

Table for the Centigrade Thermometer.

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
100	80.	212.	53	42.4	127.4	6	4.8	42.8
99	79.2	210.2	52	41.6	125.6	5	4.	41.
98	78.4	208.4	51	40.8	123.8	4	3.2	39.2
97	77.6	206.6	50	40.	122.	3	2.4	37.4
96	76.8	204.8	49	39.2	120.2	2	1.6	35.6
95	76.	203.	48	38.4	118.4	1	0.8	33.8
94	75.2	201.2	47	37.6	116.6	0	0.	32.
93	74.4	199.4	46	36.8	114.8	−1	−0.8	30.2
92	73.6	197.6	45	36.	113.	2	1.6	28.4
91	72.8	195.8	44	35.2	111.2	3	2.4	26.6
90	72.	194.	43	34.4	109.4	4	3.2	24.8
89	71.2	192.2	42	33.6	107.6	5	4.	23.
88	70.4	190.4	41	32.8	105.8	6	4.8	21.2
87	69.6	188.6	40	32.	104.	7	5.6	19.4
86	68.8	186.8	39	31.2	102.2	8	6.4	17.6
85	68.	185.	38	30.4	100.4	9	7.2	15.8
84	67.2	183.2	37	29.6	98.6	10	8.	14.
83	66.4	181.4	36	28.8	96.8	11	8.8	12.2
82	65.6	179.6	35	28.	95.	12	9.6	10.4
81	64.8	177.8	34	27.2	93.2	13	10.4	8.6
80	64.	176.	33	26.4	91.4	14	11.2	6.8
79	63.2	174.2	32	25.6	89.6	15	12.	5.
78	62.4	172.4	31	24.8	87.8	16	12.8	3.2
77	61.6	170.6	30	24.	86	17	13.6	1.4
76	60.8	168.8	29	23.2	84.2	18	14.4	−0.4
75	60.	167.	28	22.4	82.4	19	15.2	2.2
74	59.2	165.2	27	21.6	80.6	20	16.	4.
73	58.4	163.4	26	20.8	78.8	21	16.8	5.8
72	57.6	161.6	25	20.	77.	22	17.6	7.6
71	56.8	159.8	24	19.2	75.2	23	18.4	9 4
70	56.	158.	23	18.4	73.4	24	19.2	11.2
69	55.2	156.2	22	17.6	71.6	25	20.	13
68	54.4	154.4	21	16.8	69.8	26	20.8	14.8
67	53.6	152.6	20	16.	68.	27	21.6	16.6
66	52.8	150.8	19	15.2	66.2	28	22.4	18.4
65	52.	149.	18	14.4	64.4	29	23.2	20.2
64	51.2	147.2	17	13.6	62.6	30	24.	22.
63	50.4	145.4	16	12.8	60.8	31	24.8	23.8
62	49.6	143.6	15	12.	59	32	25.6	25.6
61	48.8	141.8	14	11.2	57.2	33	26.4	27.4
60	48.	140.	13	10.4	55.4	34	27.2	29.2
59	47.2	138.2	12	9.6	53.6	35	28.	31.
58	46.4	136.4	11	8.8	51.8	36	28.8	32.8
57	45.6	134.6	10	8.	50.	37	29.6	34.6
56	44.8	132.8	9	7.2	48.2	38	30.4	36.4
55	44.	131.	8	6.4	46.4	39	31.2	38.2
54	43.2	129.2	7	5.6	44.6	40	32	40

TABLES FOR REDUCING THE DEGREES OF BEAUME's AREOMETER INTO THEIR CORRESPONDING EXPRESSION OF SPECIFIC GRAVITY.

Beaumé's Areometer or Hydrometer, though not a very correct instrument, is that which from its convenience is employed very commonly by the French chemists, who are in the habit of expressing the strength or specific gravity of the acids, alcohol, &c. which they employ by the scale of this instrument. It is described by Beaumé in his Elemens de Pharmacie, p. 466.

The form of this instrument is that of the common hydrometer, that is, a lengthened bulb or ball with a long narrow stem rising from it, which last is graduated, and the instrument is so poised that it floats with nearly the whole of the stem above the level of the heaviest liquid whose density it is to indicate, and with nearly the whole of the stem immersed when the lightest liquid is used. A single instrument would in strictness suffice to indicate the density of every liquid from the lightest alcohol to the heaviest acid, which would include a range of actual specific gravity from about .8 to 2. (water being = 1.) But an instrument of this kind must be either inconveniently long, or the stem must be very wide, and the degrees too minute for tolerable accuracy. Beaumé therefore very judiciously divided it into two scales, one of which is the areometer for spirits and liquors lighter than water, and the other the areometer for salts or liquids heavier than water. He has further distinguished them by inverting the scales, that is to say, in the instrument for salts the o. or zero is at distilled water, and the numbers increase with the *increasing* density of the liquors for which it is used; whereas in the instrument for spirits the numbers increase from the zero with the *decreasing* density. Hence it is necessary to describe these two instruments separately.

The hydrometer for salts was made by Beaumé in the following way: the instrument was first immersed in water at 18.75° Reaum. = about 50°. Fahr. and loaded with mercury dropped into the bulb till it sunk so low that only the very top of the stem was out of water, which point was marked as the o. of the scale. The instrument was then removed to a solution of common salt, containing 15 parts (by weight) of salt to 85 parts of water, and the height to which it floated was marked on the stem as 15° of the scale. The interval between these two points of immersion being therefore considered as 15 degrees, the scale was extended to any required number, merely by marking off with compasses an equal length of the stem, and the whole was farther subdivided in the same way. Beaumé considered therefore that every degree of the instrument indicated a density of liquid equal to that of a solution of common salt, in which the number of parts of salt in 100 parts, by weight, of the solution, was equal to the same number on the scale at which the instrument floated. But as the diameter of the stem is seldom equal throughout, he proposes to remedy the incorrectness produced by this circumstance, where greater accuracy is required, by immersing the instrument successively in solutions containing 5, 10, 15, &c. per cent. of salt, and marking these points as 5, 10, 15, &c. on the scale, or, to be still more accurate, all the individual degrees may be found by actual experiment. In fact, even where the stem of the instrument is perfectly cylindrical, this would be the only way to ensure perfect accuracy, as a division of equal distances on the scale would not precisely correspond with an equal increase of the percentage of salt in the solution.

The scale of this instrument does not properly extend higher than about 30°. as this is the point of saturation of water with salt, but it may be lengthened at pleasure by marking off equal distances on the scale.

The following table of correspondence between Beaumé's areometer for salts and the actual expression of specific gravity has been calculated by Mr. Nicholson, for every third degree (Phil. Journ. 4to. vol. i. p. 38.) from the datum of Morveau that the 66th degree corresponds with 1.848 sp. gr. We have added to it the specific gravities of most of the corresponding solutions of common salt in water as high as 30°. of the instrument, as given by Hassenfratz in the 28th vol. of the An. de Chim. p. 298. which ought therefore to be the same, but which actually differ in no inconsiderable degree.

We have further added the corresponding specific gravities with many of the degrees of the hydrometer from 18° to 45° as given by R. Bingley, Esq. King's Assay-master of the Mint, (Philosophical Magazine, vol. xii.) from actual experiments with a Paris hydrometer. This includes a specific gravity from 1.150 to 1.435; which, with acids, is sufficient for most of the purposes of the assayer or mineralogist.

Beaumé's Hydrometer for Salts. (Temperature 55° Fahr.)

Beaumé	*Nicholson*	*Hassenfratz*	*Bingley*	*Beaumé*	*Nicholson*	*Bingley*
1 = Sp. Gr.	1.000 =	1.0000 =		31 = Sp. Gr.		1.275
2		1.0128		32		1.283
3	1.020	1.0192		33	1.295	
4		1.0256		34		1.300
5		1.0320		35		1.312
6	1.040	1.0384		36	1.333	1.313
7		1.0448		37		1.342
8		1.0502		38		1.350
9	1.064	1.0576		39	1.373	1.358
10		1.0640		40		1.367
12	1.089	1.0775		41		1.383
14		1.0910		42	1.414	1.400
15	1.114			43		1.416
16		1.1045		45	1.455	1.435
18	1.140	1.1182	1.150	48	1.500	
20		1.1320	1.167	51	1.547	
21	1.170			54	1.597	
22		1.1462		57	1.659	
24	1.200	1.1608		60	1.717	
26		1.1760	1.216	63	1.779	
27	1.230			66	1.848	
28		1.1920	1.233	69	1.920	
29			1.250	72	2.000	
30	1.261	1.2100	1.267			

The Hydrometer for Spirits is constructed exactly on the same principle, and the mode of graduation is also the same, that is, by a solution of salt, and not by mixtures of alcohol and water of different densities. In this hydrometer the zero is placed not at the point to which the stem sinks in distilled water, but at the point to which it falls in a mixture of 10 parts of salt and 90 of water. The interval between this point and that of distilled water is marked on the scale as 10 degrees, and this scale is continued upwards on the stem simply by measuring equal portions by the compasses. The 10th degree of the spirit hydrometer corresponds with the 0. of the salt hydrometer, and it is certainly a defect that the ingenious inventor should have introduced this deviation from what is obviously the natural zero in each scale, namely, the point of immersion in distilled water; since it was as easy to obtain a measure for 10 degrees of the scale of the spirit hydrometer by beginning the notation 10 degrees below zero as at this point.

The correspondence between Beaumé's spirit hydrometer and the real expression of specific gravity has also been calculated by Mr. Nicholson, and on the following data: viz. Beaumé found that a spirit of .842 sp. gr. at 32°. Fahr. gave 37 degrees of his hydrometer; and that a mixture of two parts, by weight, of this spirit with 30 of water gave 12 degrees of the hydrometer at the same temperature.

This mixture is found by Gilpin's valuable tables to be = .9915 specific gravity at this temperature, and these terms, viz. .842 and .9915 become .832 and .9905 at 55° Fahr. or 10. Reaum. the standard temperature of the graduation of these instruments. We have given in the article Alcohol, p. 30. Vol. 1. of this work, Beaumé's table of the density of different mixtures of alcohol and water expressed in the degrees of his hydrometer, with the corresponding specific gravities as given by Hassenfratz (An. Chim. tom. xxxiii. p. 11.) we shall here repeat the latter as a comparison with those given by Mr. Nicholson, and which will further shew the degree of incorrectness of Beaumé's instrument.

Beaumés Hydrometer for Spirits. (Temperature 55° F).

Beaumé.	*Nicholson.*	*Hassenfratz.*
10	1.0000	1.0000
11	.990	
12	.985	.9863
13	.977	.9796
14	.970	.9730
15	.963	.9666
16	.955	.
16½		.9569
17	.949	
18	.942	.9474
19	.935	.
19½		.9382
20	.928	
21	.922	.9290
22	.915	
23	.909	.9172
24	.903	
25	.897	.9057
26	.892	
27	.886	0.8944
28	.880	
29	.874	
29½		.8807
30	.871	
31	.867	
32	.856	.8675
33	.852	
34	.847	.8571
35	.842	
36	.837	
37	.832	.8421
38	.827	
39	.822	
40	.817	.8276

TABLE OF THE SPECIFIC GRAVITY OF WATER AT EVERY DEGREE OF TEMPERATURE FROM 30° TO 80° FAHR.

Fahr.	*Sp. gr.*	*Fahr.*	*Sp. gr.*	*Fahr.*	*Sp. gr.*	*Fahr.*	*Sp. gr.*
30° —	1.00074	43° —	1.00090	56° —	1.00031	69° —	0.99906
31	1.00078	44	1.00088	57	1.00024	70	0.99894
32	1.00082	45	1.00086	58	1.00016	71	0.99882
33	1.00085	46	1.00083	59	1.00008	72	0.99869
34	1.00088	47	1.00080	60	1.00000	73	0.99856
35	1.00090	48	1.00076	61	0.99991	74	0.99843
36	1.00092	49	1.00072	62	0.99981	75	0.99830
37	1.00093	50	1.00068	63	0.99971	76	0.99816
38	1.00094	51	1.00063	64	0.99961	77	0.99802
39	1.00094	52	1.00057	65	0.99950	78	0.99788
40	1.00094	53	1.00051	66	0.99939	79	0.99774
41	1.00093	54	1.00045	67	0.99928	80	0.99759
42	1.00092	55	1.00038	68	0.99917		

The above Table is that which is given by Mr. Gilpin in the 84th Vol. of the Philoſophical Tranſactions, and is of eſſential uſe for taking the ſpecific gravities both of ſolids and fluids, by enabling the operator to reduce the weight or bulk of the diſtilled water employed in any caſe to that which it would have at any other common temperature, and particularly to 60° which is the uſual ſtandard. Thus, for example, ſince the ſpecific gravity of water at 47°. is 1.0008, and at 60°. is 1.00000, (and conſequently 10008 grs. at 47° are equal in bulk to 10000 grs. at 60°) it follows that it would require 252.708 grs. at 47° to equal the ſpace of a cubic inch; for 10000 : 10008 :: 252.506. (the weight of a cubic inch at 60°.) :252.708. The remarkable anomaly of the ſpecific gravity of water *decreaſing* through all the degrees of temperature below 40°. or thereabouts, that it remains uncongealed, has been noticed under the article *Water*, but the difference for one or two degrees above or below 40° is ſo trifling, that it has hardly yet been aſcertained with perfect accuracy.

TABLES RELATIVE TO THE STRENGTH OF ACIDS AND THEIR SATURATION WITH DIFFERENT BASES.

N.B. The following five Tables are extracted from Mr. Kirwan's "Additional Observations on the Proportion of Real Acid, &c." Dublin, 1799.

I.

Table of the quantities of Real Acid in 100 parts of Sulphuric Acid of different densities at 60°. Fahr.

100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*
2.0000	89.29	1.6503	62.50	1.3360	35.71
1.9859	88.39	1.6407	61.61	1.3254	34.82
1.9719	87.50	1.6312	60.71	1.3149	33.93
1.9579	86.61	1.6217	59.82	1.3102	33.03
1.9439	85.71	1.6122	58.93	1.3056	32.14
1.9299	84.82	1.6027	58.03	1.2951	31.25
1.9168	83.93	1.5932	57.14	1.2847	30.35
1.9041	83.04+	1.5840	56.25	1.2757	29.46
1.8914	82.14	1.5748	55.36+	1.2668	28.57
1.8787	81.25	1.5656	54.46	1.2589	27.68+
1.8660	80.36	1.5564	53.57	1.2510	26.78
1.8542	79.46	1.5473	52.68	1.2415	25.89
1.8424	78.57	1.5385	51.78	1.2320	25.—
1.8306	77.68	1.5292	50.89	1.2210	24.10
1.8188	76.79+	1.5202	50.00	1.2101	23.21
1.8070	75.89	1.5112	49.11+	1.2009	22.32
1.7959	75.—	1.5022	48.21	1.1918	21.43+
1.7849	74.11	1.4933	47.32	1.1836	20.53
1.7738	73.22	1.4844	46.43	1.1746	19.64
1.7629	72.32	1.4755	45.53	1.1678	18.75
1.7519	71.43	1.4666	44.64	1.1614	17.85
1.7416	70.54+	1.4427	43.75	1.1531	16.96
1.7312	69.64	1.4189	42.86	1.1398	16.07
1.7208	68.75	1.4099	41.96	1.1309	15.18+
1.7104	67.86	1.4010	41.07	1.1208	14.28
1.7000	66.96	1.3875	40.18	1.1129	13.39
1.6899	66.07	1.3768	39.28	1.1011	12.50
1.6800	65.18	1.3663	38.39	1.0955	11.60
1.6701	64.28	1.3586	37.50		
1.6602	63.39	1.3473	36.60		

II.

In 100 parts of Nitric Acid of different densities at 60°. Fahr.

100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*
1.5543	73.54	1.4018	51.47	1.2586	32.35
1.5295	69.86	1.3975	50.74	1.2500	31.62
1.5183	69.12	1.3925	50.00	1.2464	30.88
1.5070	68.39	1.3875	49.27	1.2419	30.15
1.4957	67.65	1.3825	48.53	1.2374	29.41
1.4844	66.92	1.3775	47.80	1.2291	28.68
1.4731	66.18	1.3721	47.06	1.2209	27.94
1.4719	65.45	1.3671	46.33	1.2180	27.21+
1.4707	64.71	1.3621	45.59	1.2152	26.47
1.4695	63.98+	1.3571	44.86+	1.2033	25.74+
1.4683	63.24	1.3521	44.12	1.2015	25.00
1.4671	62.51	1.3468	43.38	1.1963	24.26
1.4640	61.77	1.3417	42.65	1.1911	23.53
1.4611	61.03	1.3364	41.91	1.1845	22.79
1.4582	60.30	1.3315	41.18	1.1779	22.06
1.4553	59.56	1.3264	40.44	1.1704	21.32
1.4524	58.83	1.3212	39.71	1.1639	20.59
1.4471	58.09	1.3160	38.97	1.1581	19.85
1.4422	57.36	1.3108	38.34	1.1524	19.12
1.4373	56.62	1.3056	37.50	1.1421	18.48
1.4324	55.89	1.3004	36.77	1.1319	1765+
1.4275	55.15	1.2911	36.03	1.1284	16.91
1.4222	54.12+	1.2812	35.30+	1.1241	16.17
1.4171	53.68	1.2795	34.56	1.1165	15.44
1.4120	52.94	1.2779	33.82	1.1111	14.70
1.4069	52.21	1.2687	33.09	1.1040	13.27

III.

In 100 parts of Muriatic Acid of different densities at 60°. Fahr.

100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*	100 *parts* *Sp. gravity.*	*Real Acid.*
1.196	25.28	1.147	19.09	1.1036	13.41
1.191	24.76	1.1414	18.57	1.0984	12.90
1.187	24.25	1.1396	18.06	1.0942	12.38
1.183	23.73	1.1358	17.54	1.0910	11.86
1.179	23.22	1.1320	17.02	1.0868	11.35
1.175	22.70	1.1282	16.51	1.0826	10.83
1.171	22.18	1.1244	15.99	1.0784	10.32
1.167	21.67	1.1206	15.48	1.0742	9.80
1.163	21.15	1.1168	14.96	1.0630	8.25
1.159	20.64	1.1120	14.44	1.0345	5.16
1.155	20.12	1.1078	13.93	1.0169	2.58
1.151	19.60				

The explanation of Mr. Kirwan's term Real Acid, and the method of estimating its quantity in any mixture of acid and water, whose specific gravity is known, have been already explained under the article NITRIC ACID, p. 145. and SULPHURIC ACID, p. 273. of this volume, and need not be here repeated at length. It may just be observed, however, that by *real sulphuric acid* the author means an acid of the same density as that which forms one of the two constituent parts of perfectly dry and ignited *sulphat of potash*—by *real nitric acid*, he understands the acid of perfectly dry *nitrat of soda*—and by *real muriatic acid*, the acid of ignited *muriat of potash*.

In the above Tables the differences between the individual numbers are so small as to answer most practical purposes without further calculation, so that any specific gravity which is not set down in the Table, or *extra-tabular*, may generally be referred to that in the Table to which it is the nearest. If, however, a greater approximation to accuracy be required, the contents per cent. in real acid of any extra-tabular specific gravity may be found by the Rule of Proportion in the following way, as given by Mr. Kirwan:

Find the difference between the next higher and lower tabular specific gravities $= D$, and also the difference between their acid contents $= D'$.

Then find the difference between the extra-tabular specific gravity and the next upper or lower tabular specific gravity, whichever it is nearest to $= d$.

Then the difference between the quantity of real acid of the extra-tabular, and that of the nearest tabular specific gravity $(= d')$ will be found by the following simple Rule of Proportion, $D : D' :: d : d'$, therefore $d' = \frac{D'\,d}{D}$ and by adding d' to the acid contents of the lowest tabular specific gravity, or subtracting it from the upper, according to whichever is taken, the quantity sought will be given.

To illustrate this by a single example: What is the quantity of real acid in 100 parts of sulphuric acid of 1.790 specific gravity?

By inspecting the Table I find that 1.790 is between 1.7959 and 1.7849, consequently the tabular numbers concerned, with their respective differences, will be as follows:

	Sp. Gr.	Real Acid.	
	17959	75.00	
$D = 110$			$D' = .89$
	17849	74.11	

and d in this case is the difference between 17900 and 17849 $= 51$. The given proportions therefore are, As $110 : .89 :: 51 : d'$, therefore $d' = .413$ nearly, which added to 74.11 makes 74.523 as the quantity per cent. of real acid in sulphuric acid of 1.790 specific gravity.

This method, however, is not perfectly accurate, since it is found that the affinity of sulphuric acid to water proceeds in a decreasing ratio as the quantity of water increases, and consequently that the increase in specific gravity for equal additions of real acid pursues an increasing ratio from the bottom of the scale to the top. Therefore the value of d' as above estimated is rated a little too low.

By a similar method the specific gravity of any acid, whose contents per cent. of real acid are known, but extra-tabular, may be found. Find D and D' as before and d' is already given. Then $\frac{D\,d'}{D'} = d$ and d added to the lower specific gravity, or subtracted from the upper, gives the specific gravity sought.

IV.

Table of the quantity of Real Acid required to saturate 100 parts of Alkalies and earths.

(*Kirwan.*)

100 *Parts of*	*Sulphuric A.*	*Nitric A.*	*Muriatic A.*	*Carbonic A.*
Potash	82.48	84.96	56.3	105.
Soda	127.68	135.71	73.41	66.8
Ammonia	383.8	247.82	171.	Variable
Barytes	50.	56.	31.8	28.2
Strontian	72.41	85.56	46.	43.2
Lime	143.	179.5	84.488	81.81
Magnesia	172.64	210.	111.35	200.

V.

Table of the quantity of Alkalies and Earths required to saturate 100 parts of Real Sulphuric, Nitric, Muriatic, and Carbonic Acids. (*Kirwan.*)

100 *Parts of*	*Potash.*	*Soda.*	*Ammonia.*	*Barytes.*	*Strontian.*	*Lime.*	*Magnesia.*
Sulphuric A.	121.48	78.32	26.05	200.	138.	70.	57.92
Nitric A.	117.7	73.43	40.35	178.12	116.86	55.7	47.64
Muriatic A.	177.6	136.2	58.48	314.46	216.21	118.3	89.8
Carbonic A.	95.1	149.6	——	354.5	231.	122.	50.

From the two last Tables (supposing them to be accurate, and on the whole they appear to be the most so of any that have been ever given) the proportional quantity of acid and base in any neutral salt may be found by a simple calculation. In this state the salt is supposed to be absolutely free from water of crystallization, and at the utmost degree of dryness. Such a state however only can exist with part of the above compounds, form any of them cannot be exposed to a heat sufficient to expel the water which they contain without at the same time driving off or decomposing a portion of the acid or the base. This is the case with all the ammoniacal salts, with most of the nitrats, with the alkaline carbonats, with muriat of magnesia, &c. so that there still is wanting to complete the subject a Table of the actual composition of these and other salts at different degrees of dryness. This however we have not thought it necessary to add in this place, as we have already mentioned the composition of most of them under their respective heads, and it must be acknowledged that the considerable difference which is found in the estimations of chemists of eminence, shews the necessity of further researches, and of a much greater accuracy regulating the temperature at which desiccation is made, than is commonly observed.

TABLES OF SIMPLE AFFINITY.

(Copied from HENRY's *Epitome of Chemistry, p.* liii.)

OXYGEN.

Carbon,
Charcoal,
Manganeſe,
Zinc,
Iron,
Tin,
Antimony,
Hydrogen
Phoſphorus,
Sulphur,
Arſenic,
Nitrogen,
Nickel,
Cobalt,
Copper,
Biſmuth,
Caloric ?
Mercury,
Silver,
Arſenous acid,
Nitric oxide,
Gold,
Platina,
Carbonic oxide,
Muriatic acid,
White oxide of Manganeſe,
White oxide of Lead.

OXYGEN.*

Titanium,
Manganeſe,
Zinc,
Iron,
Tin,
Uranium,
Molybdena,
Tungſten,
Cobalt,
Antimony,
Nickel,
Arſenic,
Chrome,
Biſmuth,
Lead,
Copper,
Tellurium,
Platina,
Mercury,
Silver,
Gold.

CARBON.

Oxygen,
Iron
Hydrogen.

NITROGEN.

Oxygen,
Sulphur ?
Phoſphorus,
Hydrogen.

HYDROGEN.

Oxygen
Sulphur,
Carbon,
Phoſphorus,
Nitrogen.

SULPHUR. PHOSPHORUS ?

Potaſh,
Soda,
Iron,
Copper,
Tin,
Lead,
Silver,
Biſmuth,
Antimony,
Mercury,
Arſenic,
Molybdena.

POTASH, SODA, AND AMMONIA.

Acids. Sulphuric,
Nitric,
Muriatic,
Phoſphoric,
Fluoric,
Oxalic,
Tartaric,
Arſenic,
Succinic,
Citric,
Lactic,
Benzoic,
Sulphurous
Acetic,
Mucic,
Boracic,
Nitrous,
Carbonic,
Pruſsic,
Oil,
Water,
Sulphur.

BARYTES.

Acids. Sulphuric,
Oxalic,
Succinic,
Fluoric,
Phoſphoric,
Mucic
Nitric,
Muriatic,
Suberic,
Citric,
Tartaric,
Arſenic,
Lactic,
Benzoic,
Acetic
Boracic
Sulphurous,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus,
Water,
Fixed Oils.

STRONTITES.

Acids. Sulphuric,
Phoſphoric,
Oxalic,
Tartaric,
Fluoric,
Nitric,
Muriatic,
Succinic,
Acetic,
Arſenic,
Boracic,
Carbonic,
Water.

LIME.

Acids. Oxalic,
Sulphuric,
Tartaric,
Succinic,
Phoſphoric,
Mucic,
Nitric,
Muriatic,
Suberic,

* Vauquelin's Table of the affinity of the metals for oxygen, according to the difficulty with which their oxides are decompoſed by heat.

TABLE OF SIMPLE AFFINITY, CONTINUED.

Acids. Fluoric,
Arſenic,
Lactic,
Citric,
Malic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus,
Water,
Fixed oil.

MAGNESIA.

Acids. Oxalic,
Phoſphoric,
Sulphuric,
Fluoric,
Arſenic,
Mucic,
Succinic,
Nitric,
Muriatic,
Tartaric,
Citric,
Malic ?
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic,
Sulphur.

ALUMINE.

Acids. Sulphuric
Nitric,
Muriatic,

Oxalic,
Arſenic,
Fluoric,
Tartaric,
Succinic,
Mucic,
Citric,
Phoſphoric,
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic.

SILEX.

Fluoric acid,
Potaſh.

OXIDE OF PLATINA.
———GOLD.*

Gallic acid,
Muriatic,
Nitric,
Sulphuric,
Arſenic,
Fluoric,
Tartaric,
Phoſphoric,
Oxalic,
Citric,
Acetic,
Succinic,
Prussic,
Carbonic,
Ammonia.

OXIDE OF SILVER.

Gallic acid,

Muriatic,
Oxalic,
Sulphuric,
Mucic,
Phoſphoric,
Sulphurous,
Nitric,
Arſenic,
Fluoric,
Tartaric,
Citric,
Lactic,
Succinic,
Acetic,
Prussic,
Carbonic,
Ammonia.

OXIDE OF MERCURY.

Gallic acid,
Muriatic,
Oxalic,
Succinic,
Arſenic,
Phoſphoric,
Sulphuric,
Mucic,
Tartaric,
Citric,
Malic,
Sulphurous,
Nitric,
Fluoric,
Acetic,
Benzoic,
Boracic,
Prussic,
Carbonic.

OXIDE OF LEAD.

Gallic,
Sulphuric,
Mucic,

Oxalic,
Arſenic,
Tartaric,
Phoſphoric,
Muriatic,
Sulphurous,
Suberic,
Nitric,
Fluoric,
Citric,
Malic,
Succinic,
Lactic,
Acetic,
Benzoic,
Boracic,
Prussic,
Carbonic,
Fixed oils,
Ammonia.

OXIDE OF COPPER.

Gallic,
Oxalic,
Tartaric,
Muriatic,
Sulphuric,
Mucic,
Nitric,
Arſenic,
Phoſphoric,
Succinic,
Fluoric,
Citric,
Lactic,
Acetic,
Boracic,
Pruſſic,
Carbonic,
Fixed alkalies,
Ammonia,
Fixed oils.

* Omitting the oxalic, citric, succinic, and carbonic, and adding ſulphuretted hydrogen after ammonia.

TABLE OF SIMPLE AFFINITY, CONTINUED.

OXIDE OF ARSENIC.

Gallic,
Muriatic,
Oxalic,
Sulphuric,
Nitric,
Tartaric,
Phoſphoric,
Fluoric,
Succinic,
Citric,
Acetic,
Pruſſic,
Fixed alkalies,
Ammonia,
Fixed oils,
Water.

OXIDE OF IRON.

Gallic,
Oxalic,
Tartaric,
Camphoric,
Sulphuric,
Mucic,
Muriatic,
Nitric,
Phoſphoric,
Arſenic,
Fluoric,
Succinic,
Citric,
Lactic,
Acetic,
Boracic,
Pruſſic,
Carbonic.

OXIDE OF TIN.

Gallic,
Muriatic,
Sulphuric,
Oxalic,
Tartaric,
Arſenic,
Phoſphoric,
Nitric,
Succinic,
Fluoric,
Mucic,
Citric,
Lactic,
Acetic,
Boracic,
Pruſſic,
Ammonia.

OXIDE OF ZINC.

Gallic,
Oxalic,
Sulphuric,
Muriatic,
Mucic,
Nitric,
Tartaric,
Phoſphoric,
Citric,
Succinic,
Fluoric,
Arſenic,
Lactic,
Acetic,
Boracic,
Pruſſic,
Carbonic,
Fixed alkalies,
Ammonia.

OXIDE OF ANTIMONY.

Gallic,
Muriatic,
Benzoic,
Oxalic,
Sulphuric,
Nitric,
Tartaric,
Mucic,
Phoſphoric,
Citric,
Succinic,
Fluoric,
Arſenic,
Lactic,
Acetic,
Boracic,
Pruſſic,
Fixed alkalies,
Ammonia.

SULPHURIC ACID.
PRUSSIC.*

Barytes,
Strontites,
Potaſh,
Soda,
Lime,
Magneſia,
Ammonia,
Glucine,
Yttria,
Alumine,
Zircon,
Metallic oxides

SULPHUROUS ACID.
SUCCINIC.†

Barytes,
Lime,
Potaſh,
Soda,
Strontites,
Magneſia,
Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

PHOSPHORIC ACID.
CARBONIC.‡

Barytes,
Strontites,
Lime,
Potaſh,
Soda,
Ammonia,
Magneſia,
Glucine,
Alumine,
Zircon,
Metallic oxides,
Silex.

PHOSPHOROUS ACID.

Lime,
Barytes,
Strontites,
Potaſh,
Soda,
Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

NITRIC ACID.
MURIATIC ——‖

Barytes,
Potaſh,
Soda,
Strontites,
Lime,
Magneſia,

* With the omission of all after ammonia.
† Ammonia should come before magnesia; and stronites, glucine, and zircon, should be omitted.
‡ Magnesia should stand above ammonia, and alumina and silica should be omitted.
‖ Ammonia should stand above magnesia.

TABLE OF SIMPLE AFFINITY, CONTINUED.

Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

FLUORIC ACID.
BORACIC ——*
ARSENIC ——†
TUNGSTIC ——

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Glucine,
Alumine,
Zircon,
Silex.

ACETIC ACID.
LACTIC ——
SUBERIC ——‡

Barytes,

Potaſh,
Soda,
Strontites,
Lime,
Ammonia,
Magneſia,
Metallic oxides,
Glucine,
Alumine,
Zircon.

OXALIC ACID.
TARTARIC ——
CITRIC ——‖.

Lime,
Barytes,
Stronites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Alumine,
Metallic oxides,
Water,
Alcohol.

BENZOIC ACID.

White oxide of Arſenic,
Potaſh,
Soda,
Ammonia,
Barytes,
Lime,
Magneſia,
Alumine.

CAMPHORIC ACID.

Lime,
Potaſh,
Soda,
Barytes,
Ammonia,
Alumine,
Magneſia.

FIXED OIL.

Lime,
Barytes,

Potaſh,
Soda,
Magneſia,
Oxide of Mercury,
Other metallic oxides,
Alumine.

ALCOHOL.

Water,
Ether,
Volatile oil,
Alkaline ſulphurets.

SULPHURETTED HYDROGEN.

Barytes,
Potaſh,
Soda,
Lime,
Ammonia,
Magneſia,
Zircon.

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* Silex should be omitted, and, instead of it, water and alcohol be inserted.
† Except silex.
‡ With the omission of strontites, metallic oxyds, glucine, and zircon.
‖ Zircon after alumine.

EXPLANATION OF THE PLATES.

The twelve firſt Plates repreſent various articles of chemical apparatus, all of which have been particularly deſcribed in Appendix I. It will therefore only be neceſſary in this place to give the names of the different articles, and refer the reader to the ſame names in the firſt Appendix for their conſtruction and uſes.

Plate 1.

Fig. 1. A long-necked Retort for procuring gaſſes.
2. A Tubulated Retort.
3. An Adopter.
4. A tubulated or quilled Receiver.
5. A common Retort for diſtillation.
6. A Balloon Receiver.
7. A ribbed glaſs Funnel.
8. A ſmall Matraſs.
9. An earthenware Evaporating veſſel.
10. An iron Sand-Bath-pot.
11. A tubulated Retort, into which fits
12. An Acid-Holder.
13. 14, 15. Proof Bottles.
16. A plain Jar.
17. A Bell Receiver.
18. A graduated or Eudiometer Jar.
19. A lipped Jar for mixtures, &c.
20. A Precipitating Glaſs.
21. A lipped Glaſs for mixtures, &c.
22, 23, 24. A common Crucible with its Cover and its Stand.
25, 26, 27. A round Crucible with a Cover and Stand.
28, 29. Cupels, round and four-ſided.
30. A Muffle.

Plate 2.

31. A common Still fitted to a portable furnace.
32. A Worm-Tub or Refrigeratory.
33, 34. A copper Alembic with water bath and refrigeratory.
35. A ſmall Alembic.
36. A ſet of Aludels.
37. An Apparatus for digeſtions, an improvement on
38. A Pelican.
39. A glaſs Alembic and globe Receiver.
40. A ſeparatory Funnel.
41. A Gun-Barrel Apparatus uſed for procuring Hydrogen, &c.

Plate 3.

42, 43, 44, 45. Mr. Pepys's improved Woulfe's Apparatus, which may alſo be uſed as a Gas-ſaturating apparatus.
46. Dr. Nooth's Gas-ſaturating apparatus.
47. Dr. Hamilton's ditto
48. A flat-bottomed Matraſs.

PLATE 4.

PLATE 5.

PLATE 6.

PLATE 7.

PLATE 8.

PLATE 9.

PLATE 10. (*Frontiſpiece.*)

PLATE 11.

PLATE 12.

Plates 13, 14, & 15,

Illustrative of Crystallography.

The object in selecting the following figures with their descriptions (which are those of actual crystals) is principally to familiarize the young mineralogist with the terms of crystallography: the reader therefore will not expect to find delineations of all or nearly all the forms of crystallization to which minerals are subject. A sufficient variety, however, has, we trust, been selected to enable the student, with a little practice, to comprehend, without much difficulty, the most complex of the forms that are described in the body of this work.

All proper crystals are rectilinear solids bounded by plane surfaces or *faces:* the line of junction, or that in which two faces unite, is called an *edge*; and the point in which three or more faces unite is called a *solid angle.*

In every crystal there are two opposite ends or extremities: if they terminate in solid angles they are called *summits*, if in surfaces they are called *bases*. The faces composing the summit are called *acuminating planes* or faces of the *terminal pyramid*; and the edges by which they unite are called *edges of the pyramid.*

The plane constituting each base is called simply the *base*, and the lines by which it is bounded are called the *edges of the base.* The faces intervening between the two bases are called *lateral faces*, and the lines by which these faces come in contact with each other are called *lateral edges.*

If an edge or solid angle is cut off by the interposition of one plane, such angle or edge is said to be *truncated*, or *replaced by a secondary plane:* but if it is cut off by the interposition of two planes, the angle or edge is said to be *bevilled* or *replaced by two secondary planes*; and the line by which these secondary planes join each other, is called the *bevilling edge.*

Fig. 1 is the regular Tetrahedron, or a trihedral pyramid.
2 is the preceding with the solid angles truncated or replaced by triangular planes. *a* Truncatures.
3 is No. 1. with all the edges truncated. *a* Truncatures.
4 is No. 1. with the edges bevilled. *a* Bevilling edges.
5 is the preceding, in which the bevilling planes have entirely obliterated the original ones.
6 is the Pyramidal Octohedron, composed of two tetrahedrons joined base to base. *a* Summits, *b* acuminating faces, *c* edges of the common base.
7 is the preceding, with the summits truncated.
8 is No. 7. with secondary pyramids placed on the truncatures.
9 is No. 6. truncated on the edges.
10 is No. 6. bevilled on the solid angles.
11 is No. 6. truncated on the solid angles, and bevilled and truncated on the edges.
12 is a pyramidal octohedron, with wedge-shaped summits and a rhomboidal common base. *a* Edges of the common base.
13 14 are the Rhomboid, which may be considered either as a tetrahedral prism, or as composed of two trihedral pyramids with rhombic faces.
15 is No. 14 truncated on all the solid angles.
16 is a rhomboidal prism with dihedral summits.
17 is the preceding, with the alternate solid angles bevilled.
18 is a rhomboidal prism, truncated on the obtuse lateral edges. *a a* Truncations.
19 is the Cube, which may also be considered as a rectangular prism.
20 is the preceding, with all the edges truncated.
21 is No. 19, with all the solid angles truncated.
22 is No. 19. bevilled on all the edges.
23 is a Rectangular Prism, terminated by tetrahedral pyramids.

Fig. 24 is the preceding, bevilled on the ſolid angles of the priſm.
25 is No. 23. truncated on the lateral edges.
26 is an oblique rectangular priſm deeply bevilled on the ſolid angles.
27 is a rectangular priſm with rhomboidal ſummits.
28 is the preceding, with the lateral edges truncated.
29 is a tetrahedral table bevilled on the edges.
30 is the RHOMBOIDAL DODECAHEDRON.
31 is the preceding, with all the edges truncated.
32 is an elongated acute rhomboidal dodecahedron.
33 is the preceding, with the ſummits truncated.
34 is No. 32. with the edges of the ſummit bevilled and truncated.
35 is the regular HEXAHEDRAL PRISM.
36 is the preceding, terminated by hexahedral pyramids.
37 is No. 36. with the pyramids deeply truncated.
38 is No. 37. with the ſolid angles alſo truncated.
39 is No. 36. with the lateral edges truncated.
40 is a hexahedral priſm, with three ſuperpoſed pyramids on each baſe, the two lower of which are deeply truncated.
41 is the PYRAMIDAL DODECAHEDRON.
42 is the preceding, with the ſummits deeply truncated, and ſecondary pyramids ſet on the truncatures.
43 is the EICOSAHEDRON, with triangular faces.
44 is a *geniculated* OCTOHEDRAL PRISM.

INDEX.

N. B.—*Only those articles are introduced in this Index which will not be readily found in their proper place in the body of the work. The figures that are not preceded by Roman numerals imply the pages of the first volume. Appendix I. requires no Index, and a Table of Contents is prefixed to Appendix II. relating to weights and measures, and other useful tables.*

Printed by Wm. Phillips, George Yard, Lombard Street.

AN ACCOUNT

OF THE MOST IMPORTANT

RECENT DISCOVERIES AND IMPROVEMENTS

IN

CHEMISTRY AND MINERALOGY,

TO THE PRESENT TIME;

BEING AN

APPENDIX

TO THEIR

DICTIONARY OF CHEMISTRY AND MINERALOGY,

BY A. & C. R. AIKIN.

LONDON:

PRINTED FOR JOHN AND ARTHUR ARCH, CORNHILL;

AND WILLIAM PHILLIPS, GEORGE YARD, LOMBARD STREET.

1814.

(W. PHILLIPS, PRINTER.)

IN the following pages (intended as an APPENDIX to their Dictionary of CHEMISTRY AND MINERALOGY) the authors have endeavoured to give a perspicuous and sufficiently detailed account of the various and highly important discoveries by which the science has been enriched during the few years that have elapsed since the publication of their former volumes.

Considerable pains have been taken in verifying calculations; in collecting valuable but diffused information into one focus; in stripping it of the occasional acerbity of controversy; and in moulding the whole to that form of practical utility, which may best secure it from being superceded by future discoveries.

We trust that the purchasers of the Dictionary will not find the present Supplement unworthy of their notice.

A

ACANTICONE. See AMPHIBOLE.

ACETIC ACID. ACETITES. VINEGAR.

M. Cadet[a] has made several experiments on the manufacture of sugar-vinegar and the best proportions of ingredients. It is well known that pure sugar dissolved in water will not ferment by itself, but if yeast or leaven be added, fermentation is soon established, at first vinous, afterwards acetous. Mucilage, Extract, Fecula contributed materially to the products of fermentation, but M. Cadet has apparently been compelled in order to simplify the enquiry, to pass over very slightly the effects of these substances, and to confine himself to the operation of sugar alone. His results therefore can only be considered as affording some approximation to accuracy. To form a simple sugar vinegar he gives the following as the best proportions.

Sugar	12.4.
Leaven or Yeast .	8.
Water	86.8
	100.0

When a much greater proportion of sugar is added, a portion of it escapes fermentation, and may be procured from the vinegar unaltered. Though alcohol is the leading product of the vinous fermentation, and therefore (*cæteris paribus*) the more alcohol a fermented liquor contains, the greater quantity of acetous acid it will produce, yet the addition of alcohol to the fermenting liquor will not encrease the product of acetous acid, and if more than about $\frac{1}{17}$ of alcohol be added, the fermentation is entirely stopped and no vinegar is formed.

In making vinegar in the large way, from whatever vegetable material, whether wine, cyder, grain, carrots, sugar, &c. M. Cadet advises a previous essay of about 8 ounces of the material (if dry) with 3 pounds of water and $\frac{1}{4}$ oz. of yeast fermented completely into vinegar. To this is to be added gradually a solution of caustic potash of known strength, till the liquor is saturated (as determined by litmus, &c.) and the quantity of solid potash noted. Then for every part of potash used he estimates 1.268 parts of sugar to have been acidified by the fermentation, and hence the saccharine strength of the materials is found. Then to produce the strongest possible vinegar without leaving any undecomposed sugar, he proposes so much sugar to be added to the materials (if deficient in this principle) as will raise the proportion to 12.4 per cent. of the whole fermenting mass, which (with the 0.8 per cent. of leaven) produces as above mentioned the most favourable proportions for this manufacture.

The density of acetic acid cannot be depended on singly as any indication of the *strength* of acidity. On this subject M. Mollerat has some valuable observations.[b] The strongest acetic acid that he could obtain, which was quite pure and free from empyreuma, had the specific gravity of 1.063 at 60° Fahr. This was highly volatile when moderately heated, and entirely congealed at about 55°, and did not thaw at 72°. A given portion of it saturated 250. of carbonat of soda, and its proportion of real acid,

[a] An. Chim. tom. 62. [b] Ibid. 68.

was reckoned at 87.125 per cent. A mixture of the same acid and water in a certain proportion was made, which had exactly the same specific gravity, but its saturating power was only equal to 118 of carbonat of soda, or 58.725 real acid. A further addition of water to this last acid *diminished* the density as well as the saturating power, and this continued uniformly in every subsequent proportion of water added. On the other hand the first addition of water to the concentrated acid of 1.063 sp. gr. *encreased* the specific gravity, though the proportion of real acid was of course diminished. Hence there must be a point of the maximum of specific gravity in which the gravity would be lessened both by encreasing and diminishing the real strength of the acid as measured by its saturating power. This maximum of density M. Mollerat estimates at 1.0791 sp. gr. and 67.256 per cent. of real acid.

The observations of M. Derosne, M. Berthollet and Mr. Chenevix, which we shall presently mention, confirm this fact of a maximum density existing in this acid in a certain state of dilution. These observations however only apply to the acetic acid or *radical vinegar* obtained from some of the neutral acetates. The common distilled vinegar contains a quantity of carbonaceous matter which can only be separated by combining it with a basis and redistilling it.

Mr. Chenevix[c] has given a valuable experimental essay on acetic acid and some of the acetates. A quantity of acetite of copper was distilled *per se*, and the product separated as it came over into different portions. The first portion had the specific gravity of 1.0659, and the proportion of real acid estimated from its saturating power was 62.971. The second was 1.058 sp. gr. and 67.461 acid: the third, 1.0454 sp. gr. and 74.411 acid; the fourth, 1.040 sp. gr. and 73.295 acid.

Though these numbers do not exactly correspond with those of M. Mollerat, they shew that the specific gravity of acetic acid is no indication of its strength in real acid, and the reason of this is supposed to be the admixture of a portion of an inflammable spirit in various proportions formed during the distillation of the acetites, which has been examined by various chemists, and which the author terms *Pyro-acetic Spirit;* and M. Derosne, *Pyro-acetic Ether.*

The products of the distillation of the metallic, alkaline and earthy acetates differ remarkably in the proportions of the acid, pyro-acetic spirit, and gaseous products, though the acetates themselves are all prepared with the same acetic acid. Hence it becomes an interesting enquiry to examine what is the action of these bases on the acid during distillation, which can explain this great difference in the products. The analysis is complicated and attended with many difficulties, but the experiments of Mr. Chenevix on this subject deserve notice. The metallic acetates examined were those of silver, copper, nickel, lead, iron and manganese. A given quantity of each was distilled from a luted earthen or glass retort according to the heat required, to which was attached a tubulated matrass to collect the liquid products, a Woulfe bottle holding a solution of pure barytes, and a pneumatic trough. The heat was kept up as low as possible to effect the decomposition. The results consisted therefore of three substances which required a subsequent examination, namely, the metal or metallic oxyd left in the retort, the liquid, and the gaseous products. The metallic residue was reguline in some cases and oxidated in others, and mixed with a small portion of charcoal which was separated by dissolving the metal.

The liquid product was examined in relation to its specific gravity, its acidity, and the quantity of pyro-acetic spirit. The force of acidity was measured by the quantity of a solution of pure potash saturated by a given portion of the acid. It was more difficult to separate the pyro-acetic spirit. When alcohol is mixed with any watery liquid, the usual mode of detecting it is by the addition of carbonate of potash, but where the liquid also contains an acid which by union with potash forms a salt soluble in alcohol, this mode of separating the spirit will not answer. It was therefore necessary in the present instance to redistill from potash the liquid products of some of the acetates, and thus deprive them of their acid, before the spirituous portion could be obtained. We shall add the results of these experiments as far as concerns the liquid product in the three circumstances of specific gravity, acidity and spirit.

	Sp. Gr.	Acidity	Spirit
Acetite of Silver .	1.0656	107.309	0.
Acetite of Nickel .	1.0398	44.731	2.
Acetite of Copper .	1.0556	84.868	0.7
Acetite of Lead .	.9407	3.045	0.555
Acetite of Iron .	1.011	27.236	0.24
Acetite of Zinc .	.8452	2.258	0.695
Acetite of Manganese	.8264	1.285	0.94

[c] An. Chim. tom. 69.

Of these acetites the metallic bases of the four first were left after the process in the reguline state, the iron was the black oxyd, the zinc the white oxyd, and the manganese the brown oxyd. The enormous difference in strength of acidity which these products shew, must immediately strike the reader. The author inclines to the opinion that in proportion to the greater difficulty of the reduction of the metallic base is the quantity of spirit yielded and of acid destroyed. Thus the acetite of silver which is reduced with the greatest ease, gives an acid of much greater strength than the others, but no ascertainable quantity of spirit. On the other hand the acetite of lead, which is reduced with more difficulty, and the acetite of zinc which is not reduced at all, give a very weak acid but more spirit. It must be acknowledged however that the production of spirit bears no proportion to the destruction of acid, so that no argument can be hence derived of the conversion of the latter into the former.

When the acetites of potash and of soda are distilled *per se*, they yield a more spirituous and less acid product than any of the metallic acetites. The product from dry acetite of barytes had the specific gravity of only .8458, did not redden vegetable colours, but contained so concentrated a spirit that it was necessary to add water to enable carbonat of potash to produce any separation of spirit, and then the quantity of spirit separated was more in bulk than the entire original product of the distillation. Hence the spirit was in a more condensed state before, than after the separation. Mr. Chenevix has found the acid product distilled from acetited silver to contain the purest and strongest acetic acid and the least mixed with spirit. Its specific gravity was 1.0656 when undiluted, and its saturating power estimated at 107.309. When gradually lowered by water, the specific gravity at first *encreased* to 1.0733, but after this point again *diminished* by every subsequent dilution. This anomaly in the change of specific gravity cannot be accounted for *here* by the presence of pyro-acetic spirit, since none was detected, and the author therefore ingeniously attributes it to the strong tendency of crystallization at a moderate temperature, which this very concentrated acid possesses, and which probably acts as it does with water to produce an expansion of the liquid as it cools down to its point of congelation. The fact of the ready crystallization of the acid is undoubted, and this appears not to be owing to the presence of any spirit or extraneous matter, but rather to depend on the degree of concentration of the acid itself.

It has been maintained by some chemists that prussic acid and ammonia are among the products of the distillation of the acetates. This however is denied both by Mr. Chenevix and by Tromsdorff. The latter chemist[c] distilled acetite of soda, acetite of lead and acetite of potash, separating the volatile portion from the residue. The former was passed through an ignited tube, and carbonic acid, carburetted hydrogen and empyreumatic oil were produced, but no prussic acid nor ammonia appeared either in this or in the fixed residue.

The latest analysis of acetic acid that we possess, is one of a very interesting series on various animal and vegetable substances, performed by Messrs. Gay-Lussac, and Thenard.[d] The mode of analyzing is original, being by combustion with oxymuriat of potash, as will be further described under the article Analysis. The acetic acid was procured from acetite of potash by sulphuric acid, without any artificial heat, and the acid obtained was quite free from any admixture of the sulphuric. It was first boiled with carbonat of barytes, and the resulting acetite of barytes dried in the heat of boiling water. Thirty grammes of this salt were dissolved in water and decomposed totally by sulphat of ammonia, and the sulphat of barytes, when ignited, weighed 25.445 grammes, of which the barytes, according to the received proportions, forms 67 per cent. and hence the composition of the acetited barytes dried at a boiling water heat, is 43.17 per cent. of acetous acid, and 56.83 barytes.

This acetite was then ignited with oxymuriat of potash, and the acetic acid when reduced to its ultimate elements, carbon, oxygen, and hydrogen, gave the following proportions:

Carbon 50.224, oxygen 44.147, hydrogen 5.629.

Or, supposing all the hydrogen to be united to its saturating proportion of oxygen to constitute water, the result will be,

Carbon 50.224, water 46.911, oxygen in excess 2.865.

Four other vegetable acids were analyzed by these chemists in the same manner, namely, the oxalic, the mucous, the tartaric, and the citric, and the general results are as follow:

[c] An. Chim. tom. 58.

[d] Recherches Physico-Chimiques, &c. tom. 2.

Oxygen in each.		Carbon.	Water.
Oxalic	50.56 —	33.57 —	22.87
Mucous	36.15 —	33 69 —	30.16
Tartaric	20.71 —	24.05 —	55.24
Citric	13.44 —	33.81 —	52 75
Acetic	2.87 —	50.22 —	46.91

These analyses, if correct, give a totally different idea of the constitution of the acetic acid, compared with the other vegetable acids, from that usually entertained. It has been maintained by Westrumb, Hermbstaedt, Crell, and others, that the pure acid of vinegar was the ultimate term of oxygenation of all the vegetable acids, so that any other of these could be converted into the acetic by an oxygenating process. Thus Hermbstaedt converted the dry acid of tartar entirely into the acetous, by distillation with manganese and sulphuric acid. (*See article Acetous Acid, Ch. Dict. vol.* 1, *p.* 4.) But on the other hand the above experiments of Messrs. Gay-Lussac and Thenard shew that the acetic acid is by far the *least* oxygenated of the five vegetable acids here mentioned, but contains a much larger proportion of carbon, and hence one may expect the acetic acid to be among the *earliest* products of any acidifying process going on in vegetable matter. This, they maintain, is supported by actual observation, for the acetic acid is that into which all vegetable and even animal matter is the soonest changed, whether by distillation or the putrid fermentation, or by the action of the nitric and sulphuric acids. How, say they, should these changes take place (especially that of wine into vinegar) and no intermediate acid be found, if the acetic acid was the most oxygenated.

Pyro-Acetic Spirit. Pyro-Acetic Ether.

This substance having already been partially described in our account of Mr. Chenevix's experiments, and also having been previously examined by Derosne,* we shall here add some further notice of it. It is contained, as already mentioned, in the product of the distillation *per se*, of most of the acetites, and it is probably in many cases owing to the admixture of this spirit that the specific gravity of the distilled liquid is so much lessened as to counteract the increased density which would naturally arise from a great intensity of acid. M. Derosne obtained it in the following experiments, which were also undertaken as a general examination of the products in the usual way of preparing acetic acid. An earthen retort was filled with 41½ lbs. (French) of verdigris, and distilled *per se*, in a very gradual heat kept up for three days. The products were divided into four successive portions, each of which was kept separate. The first portion weighing 5 lbs. 10 oz. was weakly acid to the last, and of a slight blue colour.

The second was stronger and deeper coloured, and weighed 6 lbs. 4 oz.

The third, was still stronger and more blue, had a much more pungent smell, but rather empyreumatic. It weighed 7 lbs. 4 oz.

The fourth was slightly yellow, had a weak but very empyreumatic smell, and required a very strong heat to be expelled. It weighed 8½ oz.

The united weight of these four liquids was 20 lbs. 5 oz. and the cupreous residue in the retort weighed 13 lb. 14 oz. so that there was a deficiency of 7 lb. 5 oz. to make up the original weight of the verdigris employed.

A large quantity of gas was produced in the operation, the whole of which was made to pass through a separate bottle of distilled water before it escaped, to which it gave some acidity and a very disagreeable burnt flavour.

The four distilled products were again rectified and divided into successive portions, and by comparing the specific gravity of each with the power of saturating alkali, it was found that the second and third products, or those which were obtained at the middle of the first operation, were much the strongest in acid with the least specific gravity. This intermediate product being rectified at a gentle heat, gave a quantity of inflammable gas, and a light inflammable liquor, but still acid. To separate the acid, solid caustic alkali was added to it in small portions, keeping the vessel in cold water till the acid was saturated, when part of the acetited potash crystallized spontaneously, and a light yellowish liquor rose on the surface, which was carefully decanted and again rectified by distillation at a very gentle heat. The product of this last operation is the *Pyro-Acetic Ether*.

It is quite clear and colourless, its smell pungent, its taste hot and empyreumatic. It is lighter than alcohol, very volatile, and produces cold by evaporation. It is highly combustible, burning with a flame at first blue, afterwards yellowish white. After its combustion it leaves a carbonaceous stain, and if previously mixed with a little water and burned, the water remains slightly acid. It does not

* An. Chim. tom. 63.

redden litmus. When added to a solution of gold in nitromuriatic acid with a little dry muriat of lime, the Pyro-acetic ether rises to the surface with a fine golden colour. In all these respects this substance resembles the other ethers, but it differs from them in being miscible with water in any proportion.

Mr. Chenevix, in the memoir already mentioned, has examined this *Pyro-Acetic Ether* or *Spirit* with much care, and compared its properties with those of the true Acetic Ether. To obtain the Pyro-acetic Spirit, acetite of lead was distilled *per se*, in an earthen retort, and the products again rectified, and the spirit separated. Its properties are the following: It is perfectly clear and without colour; its taste burning and somewhat urinous; its smell somewhat resembling that of peppermint mixed with bitter almond. The specific gravity was at first .7929; but after rectification over muriat of lime, .7864. It burns with a white flame, leaving no residue. It boils at 130° Fahr. It mixes with water, alcohol, and the volatile oils, in every proportion; also in some proportions with the fixed oils when cold, and in every proportion when heated. It dissolves a little sulphur, more of phosphorus, and a large quantity of camphor. White wax and fat dissolve in it when hot, but a portion separates on cooling or on adding water. It dissolves a little caoutchouc which is separable again by water, and it renders a solution of gum arabic extremely turbid.

A further examination of this spirit by distillation with potash and with the mineral acids, shews some decided points of difference between the Pyro-Acetic Spirit and the Acetic Ether prepared by acetic acid and alcohol, but a fuller analysis is yet wanting.

Some chemists have attributed the production of an inflammable spirit during the distillation of the acetites to that portion of alcohol which all vinegar contains, and is derived from the vinous fermentation which always precedes the acetous. It is certain that when a large quantity of vinegar is distilled, the first portions contain a little alcohol intimately mixed with the acid. But this alcohol comes over at the first impression of heat, and certainly cannot be supposed to enter into the composition of those solid acetites (verdigris for example) that require long ebullition of the acid and metallic oxyd, and subsequent evaporation to crystallize. Yet it is from these solid acetites that the Pyro-acetic Spirit is prepared, and it rises only towards the middle and end of the distillation, when a heat much greater than is required to volatilize alcohol has been kept up for a considerable time. This Pyro-acetic Spirit or ether therefore, is obviously a product of the decomposition of some of the component parts of the acetous acid itself, and not an adventitious admixture of alcohol derived from the previous fermentation.

For some further remarks concerning the true acetic ether, see the article *Alcohol* in this Appendix.

Acetate of Alumine.

Gay-Lussac has some valuable observations on this salt, which are particularly useful to the dyer and calico-printer, who employ a vast quantity of it. When a solution of acetited alumine is heated, it becomes turbid and deposits a great deal of alumine; but (what is very remarkable) all the alumine is gradually redissolved on cooling and agitation. A second heating will again cause the alumine to precipitate, and the liquor will again become clear when cold; and this may be repeated an indefinite number of times. In a neutral solution of acetited alumine (such as is made by the calico-printers, by mixing alum and acetited lead) the author found that the quantity of alumine separated by mere heat was nearly half the whole contents. After the alumine is deposited from the heated solution, the liquor remains with an excess of acid, and hence the necessity of using chalk to saturate this excess, which however is often an injurious addition on other accounts. Alum will prevent this separation of alumine by heat.

ACETIC ETHER and SPIRIT. See the preceding article and ALCOHOL.

ACIDS VEGETABLE. See ANALYSIS.

ACTINOTE. See AMPHIBOLE.

AEROLITE or Meteoric Stone.

That stony masses, sometimes solitary, sometimes in showers, have fallen on the surface of the earth from the upper regions of the atmosphere, is a fact, which, though distinctly and particularly testified both by ancient historians and more modern observers, had gained but little credit among philosophers previously to the last twenty years. On some particular occasions indeed the evidence adduced was so circumstantial and apparently unprejudiced that nothing but the supposed impossibility of the fact prevented its reception. In the mean time new facts bearing a perfect analogy with the preceding ones continued to accumulate, and with such overpowering evidence that all *a priori* arguments gave way before them, and

the existence of atmospheric or meteoric minerals is fully admitted.

In the article *native* IRON, among the ores of that metal, the reader may find a few details relative to this subject; and a reference to another article STONES *meteoric* which by some unaccountable oversight is wholly omitted. This omission it is the purpose of the present article to supply.

Without adverting to the testimony of Livy, of Pliny, and of other ancient authors, I shall confine myself to a brief enumeration of those aerolites which have either fallen within the last twenty or thirty years, or of which, though the date of their fall is considerably more ancient, specimens are still extant, many of which have of late been submitted to chemical analysis.

Those luminous bodies called meteors or fire-balls, which make their appearance at irregular intervals, traversing with an excessively rapid motion the upper regions of the atmosphere, and ultimately falling on the surface of the earth, appear to be one source of meteoric stones. They evidently consist of a central nucleus in such a state of softness or fluidity as to admit of considerable variations in its shape; sometimes a disruption of the nucleus takes place, accompanied by an explosion, and the two or three pieces into which the mass is thus divided proceed in the direction of their previous course without any apparent abatement of velocity. More usually however the explosion is so violent as to break and disperse the meteor, and the fragments immediately fall to the ground. Of these meteors some of the most remarkable and the best observed in modern times are the following. On the 21st of May, 1676, a meteor was observed by Montanari, professor of mathematics at Bologna, and by others, passing with great velocity across the north of Italy in a direction nearly from E. to W. When it had arrived over the sea to the S.W. of Leghorn it burst with a violent explosion, and its fragments, as they fell into the sea, produced a hissing noise like that occasioned by plunging red hot iron into water.

On the 11th November, 1761, a meteor was observed in several of the provinces of France. It burst with a loud explosion into a great number of fragments in the neighbourhood of Dijon, one of which fell upon a house and set fire to it.

On the 17th July, 1771, a meteor, traversing from N. to S. was observed in England and in France. It burst with a loud explosion S.W. of Paris, causing a commotion like that of an earthquake. Its elevation above the surface of the earth, when first perceived, was more than 80,000 yards, but at the period of its explosion it had descended to about half its former elevation.

On the 18th August, 1783, a large meteor, traversing in the same direction as the preceding, was observed in various parts of England, of France, and of Italy as far as Rome. When it first was noticed, its apparent magnitude was about equal to that of the planet Jupiter, but it rapidly increased, and at the instant of its explosion was of greater apparent magnitude than the full moon. Its form varied from round to oblong, and an internal movement like that of ebullition was distinctly visible: it divided into several smaller masses, which continued in their onward course before the final explosion by which it was dissipated. The rate of its motion, according to the lowest estimate, was about 1½ mile in a second.

The diameter of the nucleus of those meteoric bodies is variously estimated at from 100 to 1000 yards; and it is obvious that a body of much inferior size, moving with an equal or nearly equal velocity, would fail to attract notice, especially in the day time, except at the period of its actual explosion. The greater number of instances of the fall of meteoric stones are under circumstances which render it probable that they too are occasioned by the exploding of meteors, which their inferior magnitude alone prevents from being visible. A loud noise, like that of thunder or the firing of heavy artillery, or the overturning of a load of stones, sometimes with, often without any visible flash, is the first circumstance which attracts notice and excites alarm, then a hissing like the noise occasioned by the passage of a shot through the air is heard; a momentary glance of the falling bodies is caught, and they are perceived entering the surface of the soil, the grass and mould being at the same time thrown up on all sides, and a sulphurous odour diffusing itself to some distance around. On immediate search being made, by digging in the direction of these holes, there is found, at the depth of a foot or two, a black roundish stone, sometimes large sometimes small, often too hot to be held in the hand, and smelling strongly of sulphur. Such are the general phenomena; the most remarkable examples are as follow:

1. In the year 1492, according to Sebastian Brandt, there fell from the sky at Ensisheim in

Upper Alsace, a large somewhat oval stone; which from this extraordinary circumstance was kept attached to a chain in the cathedral of that place. The weight of the stone was about 2 cwts. externally it was rough, dull, and of a dark colour. On being broken, it presented a close grained texture and a blackish-grey colour, and contained interspersed confusedly crystallized grains of yellow pyrites, and of grey scaly non-sulphurous iron ore attractable by the magnet, and therefore approaching to the metallic state. The specific gravity of the stone was 3.2: it did not give sparks with steel, and was pulverized without difficulty. It was analyzed by professor Barthold in the year 1797, but this analysis being performed on the entire stone, and not separately on the three substances of which it visibly consists, we can only gather from the result, that it consists of silex, alumine, magnesia, iron, sulphur and a little lime. The conclusion of the professor is, that the stone of Ensisheim is a common argillo-ferruginous mineral, and that its traditionary origin is a mere superstitious fiction.

2. On the 3d July, 1753, a shower of stones, each weighing from one to twenty lbs. and upwards, was said to have fallen during a thunder-storm at Plann near Tabor in Bohemia. One of these was deposited by Baron Born in his cabinet and described in his Lithophylacium pt. I. though he considered the account of their origin to be an idle story; and the cabinet of Baron Born coming into the possession of Mr. Greville, the specimen in question was found to form a part of it.

3. On the 20th of August, 1789, a stone 15 inches in diameter fell near Roquefort in the Landes, during the explosion of a meteor. It broke through the roof of a cottage and killed a herdsman and some cattle.

4. In the following year a shower of stones fell in Armagnac.

5. On the 12th July, 1794, about a dozen stones of various weights and dimensions fell in the neighbourhood of Sienna, in the midst of a most violent thunder-storm, at the feet of several persons, men, women, and children. They fell about eighteen hours after the enormous eruption of Mount Vesuvius, but at a distance of at least 250 miles from that volcano. One of the largest of these stones weighed upwards of five lbs. and a piece of this was brought by Sir Wm. Hamilton to England.

6. On the 17th December, 1795, a stone weighing 56 lbs. was seen by several persons to fall near Wold Cottage, in Yorkshire: as it fell a number of explosions were heard. It penetrated through twelve inches of soil and six inches of solid chalk-rock, and in burying itself had thrown a large quantity of earth to a great distance; when the stone was dug out it was warm, smoaked, and smelt strongly of sulphur. The stone itself was exhibited in London, and a piece of it was procured by Sir Joseph Banks.

7. On the 19th December, 1798, about eight o'clock in the evening, the sky being perfectly without clouds, a luminous meteor was observed by the inhabitants of Benares in India, and of the parts adjacent, accompanied by a loud noise resembling irregular platoon firing. At a village about 14 miles from the city the natives were alarmed not only by the light and the thundering noise, but with the sound as of heavy bodies falling through the air, and the roof of one cottage was actually broken through by a stone weighing above two lbs. which buried itself to the depth of several inches in the consolidated earth of which the floor was formed. The next morning the inhabitants perceived the ground to be pierced and turned up in various places, and in these on digging to the depth of some inches they found stones perfectly similar in external appearance to that which had forced its way through the roof of the hut. They were of various sizes, from about three inches to upwards of four in their largest diameter. Some of these, with a detailed account of the circumstances above related, were transmitted to England in the following year.

Thus there happened to be at the same time in England specimens from four different parts, viz. from Bohemia, from Sienna, from Benares, and from Yorkshire, of stones said to have fallen from the sky. The date of three at least of these analogous events, was so recent and the circumstantial and direct testimony in their favour was so powerful, that the narrations however extraordinary and however they might separately have been discredited, could not fail of exciting a degree of attention proportioned to their importance. One of the consequences of this was a chemical examination of these four specimens by Ed. Howard, Esq. F.R.S.* and an accurate description of their external characters and physical properties by Count Bournon.

* Phil. Trans. 1802.

The stones from Benares are covered with a thin crust of a deep black colour, without any lustre, and sprinkled over with small asperities which cause it to feel like fish-skin. Internally they are of a greyish ash colour, and of a granulated texture, like that of a coarse grit-stone. They are evidently composed of four different substances. One of these (and that which forms the greatest part of the entire mass) is in the form of distinct concretions, more or less globular, varying in magnitude from the size of a small pin's head to a pea: their colour is grey, inclining more or less to brown, and they are perfectly opake. They are easily frangible in all directions, and display a compact conchoidal fracture with a slight degree of lustre resembling enamel, the hardness is about equal to that of glass, and they give a few feeble sparks with steel. Another of the substances is reddish yellow iron pyrites, which when pulverized becomes black; it is not attractable by the magnet, and is irregularly dispersed through the substance of the stone. The third substance is iron in minute particles, and perfectly malleable: its proportion to the whole, as estimated from pulverizing the stone and separating the iron by means of a magnet, is about 2 per cent. These three substances are held together by a fourth, which is soft, of an earthy consistence, and a grey colour. The black crust by which the surface of the stone is coated, although of inconsiderable thickness, affords bright sparks when struck with steel, and appears to consist principally of magnetic black oxide of iron. The specific gravity of the entire stone is 3.35.

The stone from Yorkshire presents similar constituent parts with that from India, with the following exceptions. The distinct concretions are smaller, and of a more irregular figure. The proportion of iron pyrites is less; that of the metallic iron is considerably greater, amounting to 8 or 9 per cent. and the iron itself instead of being in minute distinct grains was in irregularly shaped pieces, some of which weighed several grains. The earthy part of the stone has rather more consistence than that of the former specimen, and greatly resembles in appearance decomposed felspar or kaolin. The specific gravity of the stone is 3.5.

The stone from Sienna was black externally, and internally was coarsely granular like the specimen from Benares. Its specific gravity was 3.41. In it might be perceived the same globular concretions, the same kind of iron pyrites, and the same grains of metallic iron, the proportion of this last somewhat exceeded that afforded by the specimen from Benares. The same kind of grey earthy substance served to connect the different parts together. But, beside the ingredients above mentioned, there were a few globules of black magnetic oxide of iron, and a single globule of a pale greenish-yellow colour; this latter was completely transparent, had a perfectly vitreous lustre and fracture, and in hardness was rather inferior to calcareous spar.

The stone from Bohemia greatly resembles that from Yorkshire. In it may be observed the same grey substance both in globular and irregular concretions, also the same particles of metallic iron, and the same kind of earthy substance connecting together the other parts. It differs however from the others in the particles of pyrites being so small as not to be visible without the help of a lens; and in the proportion of metallic iron amounting to about 25 per cent. of the entire mass. Its specific gravity was 4.28.

The ingredients being the most distinct in the specimen from Benares, was the inducement to Mr. Howard to commence his chemical examination with this. Some pieces of pyrites to the amount of 16 grains being carefully picked out from among the other substances were digested at a low heat with diluted muriatic acid. A small quantity of sulphureted hydrogen was disengaged, and after a time all that remained undissolved was earthy matter to the amount of two grains (thus reducing the real quantity of pyrites operated on to 14 grs.) and about 2 grains of sulphur. The solution was saturated with ammonia, upon which a precipitation of oxide of iron took place, and the supernatant fluid acquired a violet purple colour; this latter, having previously been found to contain not copper but nickel, was decomposed by sulphuretted hydrogen. The oxide of iron after ignition weighed 15 grains, and the sulphuret of nickel being reduced to an oxide by calcination weighed something more than one grain. From these data Mr. Howard considers the pyrites as composed of 10¼ iron, 1 nickel and 2 sulphur, estimating the per-oxide of iron to contain 55 per cent. of metal. On examination however it appears that certain difficulties or mistakes adhere to these results, which make the analysis by no means so correct as it appears to be. First, Mr. H. from his own experiments states that 100 parts of iron afford 145 grains of oxide by solution in muriatic acid precipitation by ammonia, and sub-

sequent ignition, hence this oxide contains 70 per cent. of metal; but by the concurrence of Proust, Davy, Thomson, Berzelius and all the best authorities, the per-oxide of iron contains about 52 per cent. of metal, and the protoxide 73 per cent.; hence it is evident that Mr. Howard's oxide was a mixture of the two, and was not sufficiently calcined. Secondly, allowing with Mr. H. that the real quantity of iron was 10.5 grains, this when combined with sulphur in the only two proportions in which it is capable of combining, would produce 16.5 grains of magnetic pyrites, or 21.5 of the common kind. Again, there is the distinct testimony of Count Bournon that the pyrites was not magnetic, and the equally distinct testimony of Mr. H. that it was decomposable by muriatic acid, and that a little sulphuretted hydrogen was at the same time evolved. But of the two known kinds of pyrites the magnetic alone is decomposable by muriatic acid with evolution of sulphuretted hydrogen. We must therefore either suppose some error in the analysis, or that the pyrites in question differs essentially from the only two that chemistry as yet acknowledges. In either case all that can be concluded from the analysis is the presence of much iron, of a little sulphur, and of less nickel.

After examining the pyrites Mr. H. undertook the analysis of the metallic iron of the aerolite, which being treated in the way already described in the article IRON, appeared to be an alloy of about 17 parts iron and 6 nickel.

The globular concretions were then analysed by fusion with potash in the usual way and afforded

50	silex
15	magnesia
34	oxide of iron
2.5	oxide of nickel
101.5	

Lastly, the earthy matter, which served as a cement for the three other ingredients, was examined in the same manner as the globular concretions were, and yielded

48	silex
18	magnesia
34	oxide of iron
2½	oxide of nickel
102.5	

The excess in both these analyses is no doubt to be attributed to the difference of oxydation of the iron as existing in the substance and as obtained by analysis.

The component parts of the stones from Sienna, from Yorkshire, and from Bohemia, being in too small grains to allow of their separation with sufficient exactness, a small portion of each specimen was pulverized and examined in the usual way. They all afforded silex, magnesia, the oxides of iron and of nickel, and nothing else; thus exhibiting a perfect analogy with each other and with the aerolite from Benares.

It deserves to be remarked how striking a resemblance as to their component parts exists between the earthy parts of these aerolites, and the granular peridot or olivine which is almost peculiar to basalt; this substance being composed according to Klaproth of

50	silex
38	magnesia
12	oxide of iron

It is further worthy of notice that the external characters of the small transparent globules found in the stone from Sienna for the most part agree with those of the transparent globules that occur in the cells of the supposed meteoric iron from Siberia; and that these are also strikingly similar to those of olivine.

It remains to take some notice of a few other aerolites of still more recent origin, and which have exhibited certain peculiarities in their analysis.

8. On [*] the 12th of March, 1798, the air being calm and without clouds, the inhabitants of Valence, in the Lyonnais, and its neighbourhood, were alarmed with the appearance of a meteor, accompanied by a singular noise, and exhibiting partial explosions. It was seen to fall in a vineyard, and on the day after, when the terror of the peasants had in a degree subsided, an officer of the police being present, search was made in the vineyard, a recent irregular hole of the depth of about 20 inches presented itself, at the bottom of which was found a black stone weighing above 20 lbs. On being broken it appeared to be composed of a granular ash-grey earthy matter, in which were imbedded grains of metallic iron, and of pale reddish yellow pyrites, with globular concretions of a grey colour, and some small irregular masses of a substance resembling olive coloured

[*] Journ. de Phys. 1806.

steatite. A portion of the entire stone being analysed by Vauquelin afforded

46.	silex
15.	magnesia
2.	lime
38.	oxide of iron
2.	oxide of nickel
103.	

9. On the 26th of April,[a] 1803, about one o'clock in the afternoon, the air being calm and only a few clouds floating in the sky, a brilliant meteor was observed moving rapidly from S. to N. in the vicinity of the town of l'Aigle, in Normandy. In a few seconds afterwards there was heard at l'Aigle, and all around to the distance of even 90 miles radius, a violent explosion which lasted five or six minutes: this was succeeded by three or four bursts like the discharge of cannon, and by a number of smaller explosions like musket firing, the whole being terminated by a noise like the roll of a prodigious drum. These sounds evidently proceeded from a small cloud which appeared to be nearly stationary during the whole time, and the vapours of which it was composed were thrown out on all sides during each explosion. The inhabitants of the district immediately under the cloud were also alarmed by the hissing noise as of stones discharged from slings, and at the same time a multitude of masses of solid matter were observed to fall to the ground. The area upon which these stones fell is an irregular ellipse about 7 miles long by 3 miles wide; the largest stones were found at the S. Eastern extremity of this space, the smallest ones at the opposite extremity, while the middle-sized occupied the middle of the area. The size of the stones varied from 18lbs. to a quarter of an ounce: their number could not be ascertained, but they certainly amounted to some thousands. They were so hot when they fell as to burn those who attempted to take them up, their odour was sulphureous, or rather like that arising from the discharge of gunpowder. In their external characters, and as far as can be judged from a coarse analysis of them by M. Sage, they bear a close analogy to those which have been already described.

10. On the 15th of March, 1806,[b] a loud explosion with a roll like thunder was heard at Valence Dept. Du Gard, and immediately afterwards a stone weighing about 4 lbs. was observed to fall; in its descent it broke a branch of a fig-tree and buried itself a few inches in the soil, (at the same time another stone of the weight of eight or nine lbs. was observed to fall in the adjacent district of St. Etienne). This aerolite differs greatly in appearance from all those that have been hitherto observed. It is black throughout its whole substance, and is composed of slightly adhering friable lamellæ; when rubbed on paper it leaves a grey trace not unlike that of plumbago: it acquires a kind of bituminous polish by friction, and by bruising in a mortar it is reduced to thin flat plates instead of powder. When heated it exhales a slightly bituminous odour. Its specific gravity is 1.94. Certain small granular portions of the stone were found to be attracted by the magnet. When calcined in contact with air its colour soon changed from black to red, without losing any weight; but when ignited in a small retort it remained black, gave out a little carbonic acid, and lost about 17 per cent. of its weight, which probably was water, which its porous structure enables it readily to absorb. By ebullition with muriatic acid it affords a very small quantity of sulphuretted hydrogen. It has been analysed by Vauquelin with the following result:

38.	sub-oxide of iron
30.	silex
14.	magnesia
2.	oxide of nickel
2.	oxide of manganese
2.	oxide of chrome
2.5	carbonaceous matter
90.5	
9.5	sulphur, water, and loss

An analysis of the same substance has been published by Thenard, who found in it the same ingredients as those already mentioned, but in somewhat different proportions. Mr. Howard's analyses of the aerolites related above, were not calculated to detect the presence either of manganese or of chrome; as far therefore as certainly appears, the loose texture of this stone and the presence of a little carbonaceous matter are the principal circumstances in which it differs from the other meteoric stones. If at the period of its formation or explosion it had been subjected to a high degree of heat, the iron and other metals would have been deoxygenated at the expence of the carbon, and this would probably have also induced a greater compactness of structure, in which case

[a] Journ. de Phys. 1803.

[b] Ann. de Chim. lix. p. 36. 104.

the composition and probably the external characters would have been strictly analogous to those of the other aerolites.

11. On the 22d of May 1809,[a] an aerolite, or rather several, fell at Stannern in Moravia. Of the circumstances attending its fall there is no published account; the following are the external characters of a specimen in the possession of the Count d'Unin, and procured by him on the spot. Its external surface is black, and shows evident signs of fusion. Internally it presents a pale ash-grey earthy base in which are disseminated some concretions of a darker colour, and more compact than the rest of the mass; a few dispersed grains of pyrites are also visible. The entire stone is tender, friable, and its specific gravity is 3.19. It is not attracted by the magnet, but before the blow-pipe it fuses with difficulty into a black glass, which is then acted on by the magnet. On digestion in muriatic acid it affords a very small quantity of sulphuretted hydrogen. It has been analysed by Klaproth, by M. Moser of Vienna, and by Vauquelin. The particulars of Klaproth's analysis we are unacquainted with, being only informed in general that the composition of this aerolite bears a strong resemblance to that of basalt. Vauquelin's analysis, which was performed with much care, gives the following constituent parts of the entire stone.

50.	silex
12.	lime
9.	alumine
29.	oxide of iron
1.	oxide of manganese
	nickel and sulphur, of each a trace.
101.	

Hence it appears that the Moravian aerolite is specifically different from all those that have hitherto been described, by the absence of magnesia, and the presence of lime and of alumine.

12. The last meteoric stone[b] that we shall mention is one that fell near Sigena in Arragon, in the year 1773, and was deposited in the royal museum at Madrid. In 1805 M. Proust obtained leave to analyse a portion of it, and to publish the result, with a description of the stone. Its present weight is 6 lbs 10oz. but several fragments have been broken from it: where the surface is unbroken it presents the black vitreous crust which is characteristic of most of these bodies. Its colour internally is a light bluish grey. It is an aggregate of globular concretions the largest of which are scarcely bigger than hemp-seeds, and which on examination with a lens are evidently covered over with extremely minute crystalline points. Intermixed irregularly with these concretions are particles of bronze coloured pyrites and of metallic matter. On pulverizing portions of the stone, and separating by the magnet the metallic particles, their proportion to the rest of the mass was found to vary from 17 to 22 per cent. This metallic matter was an alloy of iron and nickel in the proportion of 97 of the former to about 3. of the latter. The rest of the stone, including the pyrites, was then analysed and afforded by the usual methods,

12.	sub-sulphuret of iron
5.	black oxide of ditto
66.	silex
20.	magnesia
103.	

The excess of weight in this as in the preceding cases is no doubt to be attributed to the oxidation of the iron.

AFFINITY.

M. Berthollet, one of the most profound and eminent chemical philosophers of the age, has endeavoured to shew that it is the tendency of chemical affinity to combine bodies in all proportions, so that where any limits to this indefinite combination appear, they arise from the operation of circumstances distinct from chemical affinity, which essentially modify its action.

On the other hand it is advanced by many most ingenious chemists, and supported by a daily encreasing body of experiments, that substances unite in proportions which are rendered definite by the sole operation of their mutual affinity, and are equally definite whether only one or more compounds of the same bodies exist.

To this opinion, which has been advanced by Richter, Proust, and other eminent chemists, Mr. Dalton[a] has added a most important rule (supported by a variety of striking examples) which is, that where two bodies combine in different proportions, if the quantity of one of them be assumed as a fixed number, the proportions of the other body that unite to it are in the simplest possible ratio to each other, being produced by multiplying the lowest proportion by a simple integral number as 2, 3, 4, &c.

Thus for example, if a metal can combine

[a] Ann. de Chim. lxx. 321. [b] Journ. de Phys. 1805. [a] New System of Chemical Philosophy.

chemically with different proportions of oxygen, if 100 of the metal take 9 of oxygen for the lowest degree of oxygenation, all the other degrees will be in the proportion of 100 of metal to twice 9 (18) of oxygen; or 100 of metal to three times 9 (27) of oxygen; or 100 of metal to four times 9 (36) of oxygen, &c. &c. A reason for this simplicity in the ratio of binary compounds may be found in the general principle assumed by Mr. Dalton, which is, that in all cases the simple elements of bodies are disposed to unite atom to atom singly, or if either is in excess it exceeds by a ratio to be expressed by some simple multiple of the number of its atoms.

Hence, from the relative weights of the constituent parts of a compound, Mr. Dalton infers the relative weights of the ultimate particle or *atom* of each of these parts; and, this being found, the number of atoms of each constituent which enters into the formation of the compound particle is also deduced.

Thus (taking a compound of two constituent parts A and B. as the simplest case) if its elements are found by experiment to unite in the proportion of 5 of A to 7 of B, it is inferred by Mr. Dalton that the numbers 5 and 7 express the comparative weight of an atom of A and B. respectively. And these elements, though uniting in several proportions, will yet be found by experiment to be confined to either 5 A to 14, 21, 28, &c. of B. which is, one atom of A to 2, 3, 4, &c. atoms of B; or conversely it will be 7 B to 10, 15, 20, &c. of A, which is one atom of B, to 2, 3, 4, &c. atoms of A. It is essential to the consistency of this system therefore, that there should be no other proportions of combination between these two elements, unless indeed it be one that is expressed by an even sub-division of one of these proportions, as for example, 5 A to 7, 10½, 14, &c. of B; in which case the 10½ being resolvable into three portions of 3½ each, the number expressing the relative weight of an atom of B, must be reduced to 3½ instead of 7, and consequently the several proportions of 7, 10½, 14, and 21 of B, will be resolved respectively into 2, 3, 4, and 6 atoms of B.

To verify the numbers expressing the relative weights of an atom of A and B, (supposing that of A to be assumed as 5, and that of B as 7) let them each be examined in their separate compounds with a third body, C. Then, suppose that in the simplest binary compound of A and C, analysis discovers 3 parts by weight of C to 5 of A, it is assumed, that, as 5 is taken as the numerical expression of an atom of A, the number expressing an atom of C. must be 3; and *consequently*, if this mode of estimation be just, it will also be found by experiment that in the simplest combination of C with B, 7 parts of B will unite exactly with 3 parts of C. This supposes indeed that this simple combination of one atom of each body is known by experiment; but even if this should not be the case, the general principle will not be contravened, if, instead of a single portion of C being found, there should be a double, triple, or quadruple portion, provided the radical number or common divisor is 3, that of B being 7.

To illustrate this by an example from Mr. Dalton (in which however the numbers assumed are not perfectly accurate though sufficient for the present purpose.) The substance of which as far as we yet know the smallest relative weight enters into chemical combination is hydrogen, and on this account the weight of its atom is assumed as unity, and is the standard of comparison for the relative weight of the atom of all other bodies. The only compound of hydrogen and oxygen that we know is water, in which the oxygen is to the hydrogen as 7 to 1. The number 7 therefore is assumed as the relative weight of the atom of oxygen, and water is a binary compound containing an atom of hydrogen with an atom of oxygen in every atom of water. Sulphuretted hydrogen is composed according to Mr. Dalton of 13 parts by weight of sulphur and 1 of hydrogen. If it be assumed that an atom of sulphuretted hydrogen contains an atom of sulphur united to an atom of hydrogen, the relative weight of an atom of sulphur must be 13. To prove that this number 13 may be assumed as the weight of an atom of sulphur, let it be examined in its compounds with oxygen, and if correct, all the compounds of these two elements will contain for every 13 parts by weight of sulphur, either 7, or 14, or 21, &c. parts of oxygen, according as the compound contains to every atom of sulphur one, or two, or three atoms of oxygen.

Now according to Mr. Dalton *Sulphureous* acid actually contains 13 parts by weight of sulphur to 14 of oxygen, and therefore its atom consists of one atom of sulphur to two atoms of oxygen; and *Sulphuric* acid consists of 13 parts by weight of sulphur to 21 of oxygen, or one atom of the former to three atoms of the latter.

This hypothesis therefore is perfectly consistent in the above examples.

The comparative *weight* of each atom being thus ascertained, the relative *diameter* of the atom is found by comparing its relative weight with the specific gravity of the substance of which the atom is an integrant particle. But as this part of Mr. Dalton's system is not essential to our present purpose we shall not pursue it.

Not only do elementary atoms unite in definite proportions but also compound particles unite in the same manner. Thus both sulphuric acid and potash are compound particles, being each oxyds, the one of sulphur and the other of potassium. But as potash combines with two different proportions of sulphuric acid, one being just double the quantity of the other, the compound, *sulphat of potash*, may with propriety be considered as composed of an *atom* of potash with an *atom* of sulphuric acid, and the compound, *super-sulphat of potash*, may be considered as consisting of one atom of potash to two atoms of sulphuric acid.

Mr. Dalton gives the term *Binary* atom to any compound of two elements in which one atom of each is combined, and hence there can be but one species of binary compound of any two elements.

A *Ternary Atom* is composed of two atoms of one of the elements with one atom of the other, and hence there may be two species of ternary atoms of the same element, according as one or other is in the greater proportion. Thus an atom of nitrous oxyd is a ternary compound of two atoms of azote and one atom of oxygen; and on the other hand nitrous acid is also a ternary compound of the same elements, but consisting of one atom of azote with two atoms of oxygen.

A *Quaternary Atom* is composed of three atoms of one element with one atom of the other, and hence also there may be two species of quaternary atoms as either element predominates; and so on of the other numbers.

We shall now proceed to mention a number of facts that illustrate in a striking manner the chemical union of substances in *definite proportions*.

If one measure of pure oxygen and two measures of hydrogen be mixed in a jar over mercury and ignited by the electric spark, both the gasses will disappear, and water will be produced. If two measures of each gas be used, water will be produced as before, but one measure of oxygen will remain. Hydrogen therefore unites with water in one exact proportion, and in no other.

If a piece of well burnt charcoal be confined in oxygen gas and inflamed by a burning glass the volume of gas is not altered when again cooled, but the whole is converted into carbonic acid gas. If more oxygen be present than is necessary for the consumption of the charcoal, the products will be carbonic acid gas and an excess of oxygen; if there is less oxygen than will consume the charcoal, carbonic acid alone will be produced, and part of the charcoal will remain unconsumed.

The combination of two elements in several definite proportions is very happily shewn by the various compounds of oxygen and azote. These are nitrous oxyd, nitrous gas, and nitrous acid gas.

If two measures of *Nitrous Oxyd*, and two measures of hydrogen are ignited by the electric spark, the product is water, and two measures of azote remain. Now as water is produced by two measures of hydrogen and one of oxygen, the nitrous oxyd here employed must have consisted of two measures of azote with one of oxygen condensed into the space of one measure.

If charcoal is ignited in two measures of *Nitrous gas* the products are one measure of carbonic acid gas and one measure of azote. Hence, as carbonic acid gas always occupies the same volume as the oxygen of which it is formed, nitrous gas consists of equal volumes of oxygen and of azote not condensed by their union.

If two measures of nitrous gas be mixed over water with one measure of oxygen gas, both of them totally disappear, and a solution of *Nitrous acid gas* in water is the result.

In all the above examples the proportions of azote and oxygen encrease or diminish by equal quantities, and no intermediate states of combination are known.

Dr. Wollaston has given some striking experiments in illustration of this theory of definite proportions in the composition of some super-acid and sub-acid salts,[a] which may be here mentioned as they are easily performed. Let two grains of crystallized carbonat of potash recently prepared be wrapped in thin paper, and passed up into an inverted tube filled with mercury, and let the gas be extricated from it by muriatic acid, and the space it occupies be marked on the tube. Then let four grains of the same carbonat be exposed for a short time to

[a] Phil. Trans. for 1808.

a red-heat, and afterwards let the gas be expelled from it in the same apparatus, and it will be found to occupy exactly the same space as that obtained from the two grains of crystallized salt in the former experiment.

The same results are obtained from the super-carbonat and the sub-carbonat of soda.

Super-sulphat of potash in like manner contains twice the quantity of acid as the neutral sulphat. Let twenty grains of carbonat of potash be mixed with about twenty-five grains of sulphuric acid in a covered platina crucible, or in a glass tube, and this mixture gradually heated till it ceases to boil and becomes slightly red-hot. This will produce the super-sulphat of potash, which will be very nearly neutralized by an addition of 20 grains of the same carbonat of potash.

The common super-oxalat of potash is shewn by Dr. Thomson to consist of potash united to twice the quantity of oxalic acid necessary to saturate it. If two equal portions of this super-oxalat be taken, and one portion calcined so as to destroy the acid, the alkali that remains will be just sufficient to saturate the other portion.

When nitric or muriatic acid is added to the common super-oxalat of potash, the latter salt is only partially decomposed, and crystals form in the mixture which are found on examination to be a *Quadroxalat of Potash*, or potash with *four* times as much acid as will saturate it.

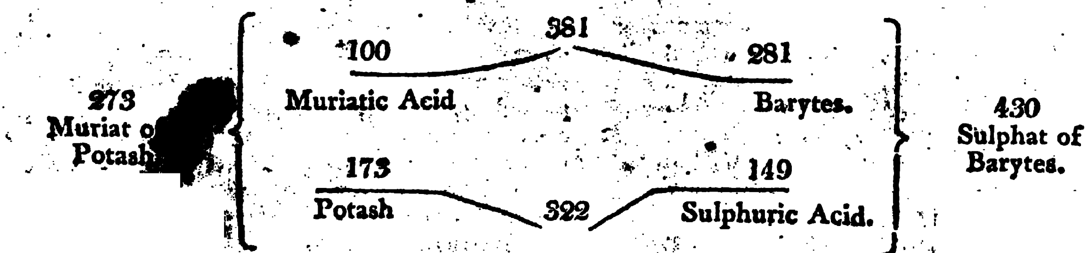
The formation of these various salts with a definite excess of acid which is expressed by a simple multiple of the least definite quantity is particularly important as it affords an answer to the powerful objection urged by M. Berthollet against the common opinion of chemical affinity. This eminent chemist shews that a considerable excess of a weaker acid will decompose a compound of a base and a stronger acid; for example, that a large quantity of nitric acid added to sulphat of potash will occasion some crystals of nitre to form, though the nitric acid has a weaker affinity to potash than the sulphuric. But though there is an undoubted decomposition of some portion of the sulphat of potash in this case, it is highly probable that for every particle of nitre formed there is an equivalent quantity of a super-sulphat of potash produced, in equally definite proportions with the neutral sulphat, and in which probably the acid is in the ratio of a simple multiple of that which exists in the neutral salt.

Among the philosophers who within these last few years have laboured with the greatest zeal and success in discovering the laws of chemical affinity a distinguished place is due to Professor Berzelius,[c] whose experiments we shall now briefly notice. He states that he was led to this train of enquiry from the two following most important theorems laid down by the learned Richter.

1. When two bodies A. and B. have each an affinity for two others C. and D. the C. which saturates a given quantity of A. is to the D. which saturates the same quantity of A. in the same proportion as the C. saturating any given quantity of B. is to the D. saturating the same quantity of B. Hence the saturating proportions of A. C. A. D. and B. C. being known those of B. D. may be found by simple calculation. For example, let A. B. C. and D. be respectively sulphuric acid, muriatic acid, barytes and potash, and let 100 parts of sulphuric acid be saturated by 190 of barytes, and by 116 of potash, and let 100 of muriatic acid be saturated by 281 of barytes, then, the quantity of potash saturating 100 of muriatic acid will be 173;

	Bar.		Pot.		Bar.		Pot.	
for	190	:	116	::	281	:	173	nearly.

This law of chemical combination is indeed a direct inference from the fact that when two neutral salts are mixed together and decompose each other the mixture remains neutral. Thus, supposing 381 parts of muriat of barytes be exactly decomposed by 322 parts of sulphat of potash, and the mixture remain neutral, the respective proportions of the new compounds formed will be 273 of muriat of potash, and 430 of sulphat of barytes, as by the following scheme:



[c] An. Chim. Tom. 77 to 83 inclusive.

The respective proportions of potash and barytes that saturate any acid are always as 173 : 281, and in the decomposition here assumed the muriatic acid that saturates these bases is 100 parts. Therefore the sulphuric acid must be 149 parts as calculated both from the elements of sulphat of potash and sulphat of barytes. In the former case 116 of potash saturate 100 parts of sulphuric acid, and 116 : 100 :: 173 : 149. In the latter case 190 of barytes saturate 100 of sulphuric acid, and 190 : 100 :: 281 : 149.

The importance of this law of chemical combination is so great that the composition of all the binary compounds might be found with absolute certainty, provided the data founded on actual experiment could be brought to perfect accuracy. Hitherto however this has not been the case, as no series of numbers representing the neutral compounds has yet been given which will apply throughout. It is a chief part of the present labours of Prof. Berzelius to correct the elements of these calculations by varied experiments conducted with great care and intelligence.

Another equally important law laid down by Richter is, that when the metal of a neutral metallic solution is precipitated by another metal, it is the metallic base alone which is changed, the oxygen and the acid remaining united with the last added metal. Hence it follows that all the different metallic oxyds which saturate a definite portion of acid contain the same quantity of oxygen. Or in other words it may be expressed that a given quantity of any acid combines to saturation with only a definite proportion of oxygen united to so much of any base as contains this portion of oxygen. Thus for example, if 100 parts of sulphuric acid saturate 20 parts of oxygen and the base united with it, the proportion of every oxyd that combines with 100 of sulphuric acid, and the composition of every neutral sulphat is known as soon as the oxyd itself is analyzed. And, conversely, the composition of any unknown oxyd may be discovered by finding the quantity of this oxyd which neutralizes a given weight of any acid whose saturating quantity of oxygen in any other oxyd is previously known. Thus, for example, if 100 parts of sulphuric acid saturate any oxyd that contains 20. of oxygen, it may be inferred that 116 parts of potash are composed of 20 of oxygen and 96 of potassium, since this quantity of potash saturates 100 of sulphuric acid. The like quantity of oxygen is therefore contained in 78 of soda, in 190 of barytes, &c. &c. each of which saturate 100 of sulphuric acid.

The late discovery of the compound nature of the alkalies and earths therefore gives an additional importance to this law of chemical affinity.

Another law of chemical combination which is laid down by Berzelius, and illustrated by numerous examples, is the following, viz. In any compound of two oxydated substances, that substance which is attracted to the positive pole of the electric circuit (the acid, for example) contains as much oxygen as is produced by multiplying the oxygen of the substance attracted to the negative pole (such as alkali, earth, metallic oxyd) by some of the integral numbers 2, 3, 4, 5, &c. For example, as 100 parts of sulphuric acid saturate as much of any oxyd as contains about 20 parts of oxygen, the quantity of oxygen in 100 parts of the acid itself must be equal to twice 20, or three times 20, &c. In this example it will be shewn presently that sulphuric acid contains almost exactly three times 20, or 60, per cent. of oxygen. Most of the other acids however contain only twice the oxygen of their saturating base: the carbonic and sulphureous acids are of this kind.

In all the compounds in which water forms an element (which are all the crystallized salts and liquid acids) this substance also seems to be subjected to some similar law of definite proportion, as will be soon explained.

We shall now give a short abstract of a few of the important series of Prof. Berzelius' experiments, to shew to what degree they illustrate and confirm the above laws of chemical combination, together with some others which will be stated in their place.

The composition of sulphuric acid which has so often been attempted was ascertained in several methods; and first through the medium of the oxyd and sulphuret of lead.

Lead and Oxygen. Lead has three degrees of oxygenation, viz. the yellow, the red, and the brown.

For the yellow oxyd, some pure lead (reduced from the nitrat of lead) was dissolved in nitric acid evaporated and ignited; a hundred parts of metal thus gained 7.8 of oxygen.

The red oxyd, or purified minium, contains to 100. of metal 11.07 oxygen.

The brown oxyd formed by digesting minium in nitric acid, contains to 100. of metal 15.6 of oxygen.

Therefore these portions of oxygen, viz. 7.8;

11.07; and 15.6, are respectively in the proportions of 1, 1½ and 2.

The yellow oxyd is the only one which enters into the salts of lead.

Lead and Sulphur. 100 parts of lead mixed with as much pure sulphur, and heated in a close vessel, as long as any sulphur was sublimed, produced 115.6 of the sulphuret; so that 100 parts of lead when thus united with sulphur absorb 15.6, which is exactly twice the weight of oxygen united with the same quantity of lead in the yellow oxyd. On this coincidence a law of combination is deduced which will be presently mentioned.

This sulphuret of lead is therefore thus composed:

Lead	100	86.51
Sulphur	15.6	13.49
	115.6	100.00

A hundred parts of the sulphuret of lead last described were digested in nitro-muriatic acid till the whole was converted into sulphat of lead, the sulphur and lead both acquiring oxygen from the nitro-muriatic acid. No product whatever was yielded from the sulphuret but the sulphat of lead, which was perfectly neutral and weighed 126.5 parts. The respective changes that took place therefore, supposing the base of this salt to be the yellow oxyd, are as follows:

			Oxygen.		
Lead -	86.51	with	6.748	produce	93.258 oxyd of lead
Sulphur	13.49	——	19.752	——	33.242 sulphuric acid
Sulphuret of lead	100.00		26.500		126.5 sulphat of lead

Two things are to be particularly noticed here:

One of them is: that the sulphur of the sulphuret of lead was exactly sufficient when converted to sulphuric acid to saturate the lead of the same sulphuret when converted to the suboxyd of lead.

The other thing to be noticed is: that the quantity of the sulphur in the sulphuret was almost exactly double the quantity of oxygen taken up by the lead of the sulphuret, being as 13.49 to 6.748.

From the former of these facts the author infers as a general rule, that a metal combines with sulphur in such a proportion, that when the sulphur is converted to sulphuric acid and the metal to an oxyd, the sole product will be a neutral sulphated oxyd of the same metal.

From the latter of these two facts the author infers: that in every neutral sulphat the oxygen of the base equals half the weight of the sulphur of the acid with which it is saturated.

The composition of sulphuric acid is inferred from the above oxydation of sulphuret of lead, to be in the proportion of 13.49 of sulphur to 19.752 of oxygen, the whole addition of oxygen to the sulphuret being 26.5, and 6.748 of this being estimated as the portion belonging to the oxyd of lead.

Sulphuric acid therefore consists of

Sulphur	40.58	—	100.000
Oxygen	59.42	—	146.426
	100.00		246.426

According to the second of the two propositions just mentioned, 100 parts of sulphuric acid therefore will saturate so much of any oxydated base as contains $\frac{40.58}{2} = 20.29$ of oxygen.

As an exact determination of the elements of sulphuric acid is of great importance in analysis, the author proceeds to compare the above mentioned result with those produced by other modes of operating.

Both Bucholz and Klaproth have sought to fix the elements of this acid by acidifying a given quantity of sulphur, and then combining it with the barytes of a known quantity of some soluble barytic salt. The analysis of sulphat of barytes depends also on that of carbonat of barytes, out of which all the barytic salts are prepared. By multiplied experiments the author fixes the elements of carbonat of barytes at

Carbonic acid	21.6	—	100
Barytes	78.4	—	363
	100.0		463

Of this carbonat, 100 parts (containing 78.4 of base) gave from 118.6 to 119 parts of sulphat of barytes, which will give for the elements of sulphat of barytes within $\frac{1}{1000}$ of the following numbers:

Sulphuric acid	34	—	100
Barytes	66	—	194
	100		294

Bucholz acidified 100 parts of fused sulphur with nitro-muriatic acid, and by combining with barytes the sulphuric acid thus produced obtained 724 parts of sulphat of barytes. If this sulphat is estimated according to Berzelius' result above given, its acid part will be 246.16, whence 100 parts of sulphur will have combined with 146.16 of oxygen, and this estimation of sulphuric acid will be found to correspond almost exactly with that already given as found by the acidification of sulphuret of lead.

Sulphureous Acid. The production of this acid by the direct combustion of sulphur being attended with nearly insuperable difficulties, Pr. Berzelius attempted its analysis by means of the sulphite of ammonia. This salt was decomposed by muriat of barytes, and the resulting sulphite of barytes was changed to the sulphat of barytes, by means of nitric acid, none of the sulphureous acid being expelled in the process. By these and other experiments the author determines the elements of sulphureous acid to be

Sulphur	50.57 —	100.00
Oxygen	49.43 —	97.83
	100.00	197.83

The oxygen in the sulphureous acid is therefore to that in the sulphuric acid very nearly as $1:1\frac{1}{2}$; as 100 parts of sulphur unite with 97.83 of oxygen in the sulphureous, and with 146.426 in the sulphuric, and $79.83 \times 1\frac{1}{2} = 146.785$.

Copper with Sulphur and Oxygen.

The author proceeds to examine the compounds of copper with sulphur and oxygen, to ascertain whether they agree with those of lead in the three laws of combination which he had laid down. These laws (to repeat them) are the following:

1. That the sulphuret of any metal, when oxydated, is totally changed to a neutral sulphat.

2. That in every sulphat the oxygen belonging to the base equals half the weight of the sulphur in the acid.

3. That in every compound of an acid and a base, the oxygen of the acid equals that of the base multiplied by some integral number. To this may be added the other law of all chemical combination (which is entirely adopted by the author) namely,

4. That where two bodies unite in different proportions, if the quantity of one of them be assumed as a fixed number, the proportions of the other body are in the simplest ratio to each other, being produced by multiplying the lowest proportion by some integral number.

Copper and Sulphur. One hundred parts of copper heated in a retort with as much sulphur, till all the excess of the latter was expelled, produced 125.6 of sulphuret of copper. Some difficulties attend this operation to produce uniform results, but the above number appears to approach the nearest to accuracy. Hence from this single fact, the following composition of the suboxyd and sulphated suboxyd of copper should be made out, assuming that the oxyd of copper corresponding with this sulphuret is at a minimum of oxydation.

Copper	100.0	with 12.800 oxygen give	112.800	suboxyd of copper
Sulphur	25.6	37.485	63.085	sulphuric acid
Sulphuret of Copper	125.6	50.285	175.885	Sulphated Suboxyd of Copper

This therefore would give for the composition of the suboxyd of copper,

Copper	100.0 —	88.652
Oxygen	12.8 —	11.348
	112.8	100.000

And the sulphated suboxyd of copper would consist of 63.085 acid to 112.8 of suboxyd: or as follows: (the oxygen of the base equalling half the sulphur in the acid).

Sulphuric acid	100.0 —	35.87
Suboxyd of copper	178.8 —	64.13
	278.8	100.00

Now, supposing the *Peroxyd* of copper to contain twice the quantity of oxygen to a given weight of metal, as the suboxyd, this peroxyd of copper would consist of

Copper	100.0 —	79.618
Oxygen	25.6 —	20.382
	125.6	100.000

Then if this peroxyd were the base of a neutral sulphat of copper, this sulphated peroxyd would contain

Sulphuric acid	100.000 —	50.113
Peroxyd of Copper	99.548 —	49.887
	199.548	100.000

since 99.548 would be the quantity of this peroxyd that contains oxygen equal to half the sulphur in the acid.

Lastly, if this latter sulphat were formed by the direct oxygenation of a super-sulphuret of copper, this would of course contain a double proportion of sulphur, and its proportions when resolved would be as follows:

		Oxygen.		
Copper -	100.0	with 25.60	give 125.60	peroxyd of copper
Sulphur -	51.2	74.97	126.17	sulphuric acid
Super-sulphuret	151.2	100.57	251.77	Sulphated Peroxyd of Copper

The author then proceeds to examine the accuracy of these hypothetical numbers by actual experiment. We shall state them in a very few words.

The peroxyd of copper was formed by evaporating and igniting a given weight of metal dissolved in nitric acid. Another portion of the nitrat was decomposed by a carbonated alkali, and the precipitate ignited. In the former case some of the metal was volatilized with the acid, and in the latter a portion was left in the solution and separated by sulphuretted hydrogen, both of which circumstances produce some little inaccuracy in the results. An allowance must also be made for the sulphur and carbon retained by all copper. If this be fixed at ½ per cent. (which however is quite arbitrary) the composition of the peroxyd of copper will be

Copper	80	—	100
Oxygen	20	—	25
	100		125

which very nearly agrees with the proportion deduced from the sulphuret.

The suboxyd of copper was formed by mixing 10 parts of the peroxyd with the same quantity of pure copper in a flask, containing 75 parts of muriatic acid, and keeping the vessel well closed on a gentle stove-heat for three days, with frequent shaking. After this the whole of the peroxyd and part of the copper were dissolved, and the quantity of the latter was found by weighing the undissolved portion. Then supposing the oxygen of the peroxyd to be equally divided between its own portion of metal and that added, and the whole to constitute the suboxyd, this will nearly contain half the oxygen of that in the peroxyd, allowing a small deviation to be produced by the unavoidable action of the muriatic acid on a small portion of the copper, independently of the oxygen present, which was shewn by an escape of hydrogen when the vessel was opened. A suboxyd of copper containing half the oxygen of the peroxyd, will therefore consist of

Copper	88.89	—	100.0
Oxygen	11.11	—	12.5
	100.00		112.5

This very nearly agrees with the result of a similar experiment made by Mr. Chenevix, who reckons 13. of oxygen to 100. of metal; and the composition of this suboxyd estimated from the sulphuret is the mean of these two, or 12.8 of oxygen.

The common sulphat of copper was then analyzed: 5 parts of this salt dried at a tin-melting heat and decomposed by muriat of barytes, gave 7.22 of sulphat of barytes, the acid of which is 2.455, leaving therefore 2.545 for the oxyd of copper in the 5 parts. The basis of this salt is the *peroxyd* of copper, and therefore this salt is properly the sulphated peroxyd of copper. It is thus composed, from the above analysis:

Sulphuric acid	49.10	100.00
Peroxyd of copper	50.90	103.66
	100.00	203.66

On the other hand, if 100 parts of sulphuric acid neutralize so much of any base as contains 20.29 parts of oxygen, it would require 101.45 instead of 103.66 of the peroxyd.

The quantity of peroxyd saturating 100. of sulphuric acid, as estimated by the composirion of the sulphuret, is 99.548, which is still sufficiently near 103.66 to come within the limits of probable error.

The above experiments on the compounds of copper with sulphur and oxygen are so far defective that they do not exhibit any super-sulphuret of copper, which is the regular base of the common sulphat of copper or sulphated peroxyd: nor on the other hand do they shew any sulphated suboxyd of copper, which is the regular product of the oxydation of the subsulphuret actually known. They sufficiently illustrate, however, the law of definite proportions in the different degrees of oxydation; and that

of a precise portion of oxygen in the oxyd saturated by a given quantity of sulphuric acid.

Iron, Sulphur and Oxygen.

We shall briefly mention these, on account of an apparent anomaly in the relation between the sulphuret and sulphat as already laid down.

Subsulphuret of Iron. This was formed by heating red-hot for a considerable time a mixture of thin iron plate and thrice its weight of sulphur, till all the excess of the latter was sublimed. The remaining sulphuret of iron was brilliant, brittle, and magnetic only in powder. A given portion of it was analyzed by being first totally dissolved and acidified in nitro-muriatic acid, and the sulphuric acid thus generated was separated by muriat of barytes and the oxyd of iron by ammonia. Reckoning 34 per cent. of acid, or 13.797 of sulphur, in sulphat of barytes, and 69.3 per cent. of iron in the peroxyd here produced by the action of the nitro-muriatic acid, this subsulphuret of iron would consist nearly of

Sulphur . .	37	—	58.75
Metallic iron	63	—	100.00
	100		158.75

The super-sulphuret of iron, or natural crystallized pyrites, gave by a similar analysis,

Sulphur .	53.92	—	117
Iron . .	46.08	—	100
	100.00		217

Therefore the sulphur combined with 100 parts of iron is twice as much in the supersulphuret as in the subsulphuret.

Oxyds of Iron. This very important subject has been examined here with peculiar care. It was first asserted by Proust, and has been pretty generally allowed, that there are but two oxyds of iron, the black and the red oxyd, the former being the suboxyd and the latter the peroxyd. That there are these two distinct oxyds is not doubted, but Thenard has given some experiments which appear to establish another oxyd of a still lower degree of oxygenation than the black oxyd, and which when first separated from its solution is *white.* If this be correct, there are three oxyds, namely, the white, the black, and the red, of which the latter has the highest proportion of oxygen. The existence of this white oxyd is also probable on account of the ratio of oxygenation, as will be further mentioned here, and also in the article *Iron* in this Appendix.

At present however only the black and the red oxyd are concerned, which may be here termed the Suboxyd and the Peroxyd.

The composition of these as determined by Berzelius from many experiments, is the following.

For the suboxyd

Iron .	77.22	—	100.0
Oxygen	22.78		29.5
	100.00		129.5

For the peroxyd

Iron .	69.34	—	100.00
Oxygen	30.66		44.25
	100.00		144.25

Therefore the oxygen of the peroxyd is to that of the suboxyd only as $1\frac{1}{2}$. to 1. for $29.5 \times 1\frac{1}{2} = 44.25$.

But on the other hand the sulphur of the super-sulphuret is twice the proportion of that in the sub-sulphuret: and therefore if each of these sulphurets were acidified and converted into a sulphat of iron (the base of the sulphat corresponding with the sub-sulphuret being the suboxyd, and that of the other sulphat being the peroxyd) it is evident that the laws that regulate this change as deduced from the sulphuret and sulphat of lead could not be preserved.

The combinations that would take place are as follows.

The sub-sulphuret converted into a sulphated suboxyd would give

			Oxygen.		
Iron . .	100.00	with	29.50	. give	129.5 Suboxyd
Sulphur .	58.75	—	86.03	. —	144.78 Sulphuric acid
Subsulphuret	158.75		115.53		274.28 Sulphated Suboxyd

In this case all the laws of combination are observed pretty accurately, the sulphuric acid saturating so much of the base as contains oxygen equal to half the sulphur in the acid, within a trifling difference. But on the other hand, if the supersulphuret of iron or the natural crystallized pyrites (which contains a double proportion of sulphur) were totally

oxydated in the same way, and converted into a sulphat with the peroxyd for its base, it is obvious that the same relative proportions between the sulphat and the sulphuret could not be preserved, as the peroxyd is an oxygenation of only 1¼ the quantity of the suboxyd, whereas the supersulphuret is a sulphuration of twice the quantity in the subsulphuret. This compound therefore, if it could exist, must be one with a double portion of acid as follows:

			Oxygen.				
Iron . .	100.00	with	42.25	.	give	144.25	Peroxyd
Sulphur .	117.50	—	172.06	.	—	289.56	Sulphuric acid
Supersulphuret	217.50		214.31			433.81	Supersulphat

The resulting salt in this case therefore must be with excess of acid, for 289.56 : 144.25 : : 100 : 49.82 so that 100. of sulphuric acid would only unite with 49.82 of the peroxyd of iron which contains only 15.27 of oxygen; whereas it is found by all the previous experiments that 100. of sulphuric acid requires for its saturation as much of any oxyd as contains 20.29 of oxygen, or thereabouts.

But the actual composition of the sulphated peroxyd of iron (or *red sulphat*) is very different. Berzelius finds it by experiment to contain about 100 sulphuric acid to 65.5 peroxyd, which are resolved into the following numbers.

			Oxygen.			
Sulphuric acid	100	contain	59.42	with	40.58	Sulphur
Peroxyd . .	65.5	——	20.10	—	45.40	Iron

These numbers agree sufficiently well with the laws of combination all along observed, for the oxygen of the peroxyd is very nearly half the weight of the sulphur in the acid, and 100 parts of the acid saturate as much peroxyd as contains 20.1 of oxygen. Therefore the sulphuret of iron, which is the base of this sulphat, is one in which the sulphur is to the iron as 40.58 : 45.40 and would therefore consist of

Iron	100.
Sulphur	89.38
	189.38

which is an intermediate degree of sulphuration between the two actually ascertained by experiment. A sulphuret not far deviating from these proportions has been actually produced by Mr. Hatchett by distilling the magnetical pyrites with sulphur in a low red heat, as mentioned in our original article IRON.[a]

Muriatic Acid.

A perfect analysis of muriat of silver that could be depended on even to a thousandth part is a great desideratum, as it would afford a means of ascertaining the muriatic acid in all the other muriats, and also the quantity of oxygen contained in the base of all these salts, if the hypothesis of equal saturation of acids by so much of every oxyd as contains a given portion of oxygen be correct. There is no great difficulty in ascertaining the quantity of metallic silver in a given portion of the fused muriat of silver, but it is not so easy to find the exact proportion of oxygen that unites to the metal and of muriatic acid. It is thus attempted by Professor Berzelius.

Muriat of Silver. 100 of ignited carbonat of barytes contain by experiment 21.6 of carbonic acid, and therefore 78.4 of barytes, which last when saturated with muriatic acid gives 105.6 of muriat of barytes, which salt therefore contains 78.4 of barytes, and 27.2 of acid. Hence the elements of muriat of barytes are

Muriatic acid	25.75	100.0
Barytes . .	74.25	288.4
	100.00	388.4

On the other hand 105.6 of muriat of barytes decomposed by nitrat of silver produce 145.5 of fused muriat of silver, which last therefore contains all the acid in 105.6 muriat of barytes, namely, 27.2 parts, and 144.5 : 272 : : 100 : 18.7. Therefore 100. parts of muriat of silver contain 18.7 acid and 81.3 oxyd of silver.

Likewise, 100 parts of silver being dissolved in nitric acid, muriatic acid added in excess, and the whole evaporated and fused gave 132.7 of muriat of silver, the metal of which therefore is 100. parts, or (reduced to the proportion of 100 parts of the muriat of silver) this will contain 75.358 per cent. of silver, and 24.642 oxygen and muriatic acid.

But as muriat of silver has already been shewn to contain 18.7 per cent. of muriatic acid, the difference between 24.614 and 18.7, or 5.942, is the oxygen.

[a] See Chem. Dict. vol. 1.

From these data therefore the fused muriat of silver is thus composed:

Muriatic acid		18.7			100.000
Silver	75.358	81.3	Silver	402.984	434.759
Oxygen	5.942		Oxygen	31.775	
		100.0			534.759

And the oxyd of silver will consist of

silver	92.67	100.000
oxygen	7.33	7.925
	100.00	107.925

Therefore 100 parts of muriatic acid saturate so much of this base as contains 31.775 of oxygen, and if the rule of equal saturation be just, every base that saturates 100. parts of dry muriatic acid will contain 31.775 of oxygen, provided this analysis of muriat of silver be correct.

Another mode of analysing muriat of silver is by means of the sulphuret. Sulphuret of silver the author finds to consist of 100 silver to 14.9 sulphur; sulphuret of lead contains 100 lead and 15.42 sulphur; and suboxyd of lead contains 100 of lead to 7.7 oxygen. Then, applying Richter's rule, the sulphur saturating 100 parts of lead, is to the oxygen saturating 100 of lead, in the same proportion as the sulphur saturating 100 of silver is to the oxygen saturating 100 of silver. This will give 7.44 for the oxygen saturating 100 of silver; for 15.42 : 7.7 :: 14.9 : 7.44. If this result be taken in conjunction with the fact that 100. of silver produce 132.7 of the muriat of silver, this 132.7 of muriat will consist of 100. of silver, and 7.44 of oxygen, leaving 25.26 for the muriatic acid. This would give as much as 19.035 per cent. of muriatic acid in muriat of silver, and only 6.925 per cent. of oxygen in the oxyd of silver; and would give only 29.455 for the oxygen in the base saturated by 100. of dry muriatic acid.

As the latter mode of estimating muriat of silver is obviously exposed to many more sources of inaccuracy, the former is preferable. All things considered, the disagreement between the two is not very great, though sufficient to render it unsafe to take the mean number as the most accurate. We may therefore for the present infer that a dry saturated muriat (retaining the old theory of muriatic acid) contains for every 100 parts of muriatic acid about 31.5 of oxygen in the base which saturates the acid.

The author examines the muriats of copper and lead with this view. The particulars we shall not here give, but the results considerably confirm this general law of equal saturation above mentioned.

On Water of Crystallization and Water of Composition.

Water according to Berzelius performs the part of a base when united to an acid, and of an acid when in union with a base. Some acids cannot exist in a separate state unless combined with a certain portion of water, which portion is exactly sufficient to oxydate that quantity of any metal which will combine with the acid to form a neutral compound. This is the case most remarkably with the muriatic acid, and also with the sulphuric, which last can never be concentrated singly to a greater degree than that at which it retains as much water as contains oxygen equal to half the sulphur in the acid itself, this being the proportion required in the bases saturating this acid as has been already fully described. Hence the impossibility of forming sulphuric acid by the combustion of sulphur in dry oxygen without the presence of water; and hence when the dry sulphats, such as alum, are distilled *per se*, the product is not sulphuric acid, but only its elements sulphureous acid and oxygen. The same takes place with the nitric acid, which can never be produced by the mere distillation of the dry nitrats that contain no water of cyrstallization, as these when heated yield only oxygen and nitrous acid gas till water be added.

Besides this *water of composition* there exists (often in the same compounds) another portion, which is the *water of crystallization*, and there seems some reason to infer from the author's numerous experiments, that the quantity of water of crystallization is such that its oxygen is always a multiplication or a division of

that of the base by an integrant number. Some of the experiments we shall mention.

Tartaric Acid, 100 parts of this acid well dried, were dissolved in water, and decomposed by acetited lead. The resulting tartrite of lead weighed 235.1. Five parts of this tartrite were then decomposed by sulphuric acid, and gave 4.22 of sulphat of lead, the composition of which being already known, that of tartrite of lead was inferred to be 164.87 oxyd of lead (containing 11.79 oxygen) to 100 of pure tartaric acid. Hence the 235.1 of tartrite of lead before mentioned contained 88.75 of tartaric acid free from water, and 11.25 of water; or, (in the same proportions) 100. parts of pure tartaric acid combine with 12.7 of water, containing 11.2 of oxygen. As this 11.2 does not very much differ from 11.79, it may therefore be inferred (making allowance for inaccuracy of experiment) that the water and the oxyd of lead saturating 100 parts of pure tartaric acid contain the same quantity of oxygen.

Citric Acid. 100 parts of dry citric acid were dissolved in water, mixed with 300. of oxyd of lead, evaporated to dryness and dried for some hours at a heat above boiling water. The residue weighed 379. parts, and hence there was a loss of water from the acid amounting to 20.85 per cent. Another 100. parts of the same citric acid combined with lead from the acetite, as in the foregoing experiments with tartaric acid, gave 237.56 of citrat of lead. Another 100. of the same citric acid heated on a sand bath till it first melted and then hardened, but without decomposition, lost 7.08 of water. 100. parts of the citrat of lead treated with sulphuric acid, gave 90.56 of sulphat of lead, which contain 66.66 of oxyd of lead, and hence the composition of citrat of lead is 1. of acid to 2. of oxyd of lead. From these data the inferences (which need not be gone over at length) are, that 100 parts of mere citric acid saturate as much oxyd of lead as contains 14.13 oxygen: that 100 parts of the crystallized acid contain 20.85 of water, 7.08 of which may be repelled by heat alone, and may therefore be considered as *water of crystallization*; and the remaining 13.77 is the *water of composition*, and the former is (within a trifling difference) half the latter. Moreover, 100. of real citric acid will unite to 17.14 of water of composition (which here acts the part of a base, as it is expelled only by displacing it by the intervention of another base) and this 17.14 of water contains 15 of oxygen; and this quantity of acid also combines with 8.52 water which contains half this quantity of oxygen. Hence (making large allowance for inaccuracy) the oxygen of the water of crystallization in citric acid being taken as 1. that of water of composition, and also that of the saturating portion of oxyd of lead are each about 2. which agrees with the law of composition laid down.

Many other saline substances examined by the author were found tolerably well to agree with the above law. For example, 100 parts of crystallized sulphat of iron contain the following elements, viz.

Sulphuric acid	— —	28.9	containing	17.34	oxygen
Suboxyd of iron	— —	25.7	—	5.8	
Water	— —	45.4	—	40.16	

therefore the oxygen of each of these three elements is respectively in the proportion of 1.3 and 7.

The author gives many other experiments on this subject from which he deduces the following law, namely, that in every compound of three or more oxydated substances, the oxygen of that constituent part which contains the least quantity of it is a common divisor for the other quantities of oxygen. And where one of the compounds is *water* its oxygen is equal to that of the base multiplied by some integral number. But it does not always happen that the oxygen in the water bears the same simple ratio to that of the acid; though each of them are measured by a simple multiplication of that of the lowest base. Thus in the case just stated, the oxygen of the water is to that of the base as 7 to 1, and that of the base is to that of the acid as 1 to 3; but that of the water is to that of the acid as 7 to 3, which is a ratio that cannot be expressed by an integral number.

ALALITE. See AUGITE.

ALAUNSTEIN.

A specimen of this mineral was found by Klaproth[a] to contain

55.5	silex
19.	alumine
16.5	sulphuric acid
4.	potash
3.	water
98.0	

[a] Journ. de Phys. lxxi. 412.

From the concurrence of this analysis with that of Vauquelin, it may be concluded that the above are the ingredients which enter into the compostion of the alum-stone of La Tolfa. The difference in the respective proportions obtained by these able chemists depends in part, no doubt, on a want of perfect uniformity in different portions of the mineral itself.

ALBUMEN.

Dr. Bostock has given some useful observations concerning this substance.[a] When white of egg is coagulated by heat and then long digested in water, about a fourth part is dissolved, the remainder being untouched. White of egg also loses about 80 per cent. of its weight by gentle drying, which loss appears to be pure water. When water containing only a thousandth part of pure albumen is heated to boiling its presence is indicated by a perceptible opacity. The *pure* albumen here mentioned is reckoned to constitute 15½ per cent. of the entire white of egg. A solution of albumen of the above strength is rendered milky by a few drops of corrosive sublimate solution, and after a while a curdy precipitate collects. Nitro-muriat of tin has a similar effect but is not quite so powerful. Equal parts of an infusion of galls (half an ounce to half a pint of water) and a solution of $\frac{1}{1000}$ of pure albumen form a precipitate after standing a time. Goulard's extract (a saturated solution of litharge in hot vinegar) precipitates albumen very speedily.

Most of these and other substances which coagulate albumen also act upon other animal fluids, but Dr. B. considers the coagulation by heat alone and by corrosive sublimate as exclusively belonging to albumen when compared with jelly and mucus. When corrosive sublimate is first added to a solution of albumen and heat afterwards applied, the coagulation is very complete, and the coagulum separable from a very dilute solution, but then it is a solid compound of albumen with oxyd of mercury. The solution of tan, though considered as the appropriate precipitant of jelly, will also affect a solution of albumen, though not to the same degree, and the compound precipitate of tan and the animal matter is not so dense and separable from the liquid when albumen is present.

Almost every metallic solution is precipitated by albumen,[b] and this precipitate then consists of acid, metallic oxyd and albumen, but it is again soluble more or less completely in an excess of albumen. Hence it may be inferred that it is the albumen which holds in solution the oxyd of iron met with in the blood.

Mr. Brande has given some very valuable facts respecting the detection of small quantities of albumen by the galvanic action.[c] When the conductors from a galvanic battery are brought near each other in white of egg, an immediate and rapid coagulation takes place at the negative wire but only a thin film of albumen forms at the positive wire. This has been explained on an idea first suggested by Dr. Thompson, namely that the fluidity of albumen depends on the presence of alkaline matter, the separation of which at the negative pole causes the albumen to assume a solid form.

Pursuing this idea, Mr. Brande coagulated some white of egg by heat and then extracted by hot water that portion of the coagulum which (as observed by Dr. Bostock) is again soluble in water, this solution was then exposed to the galvanic action, and a copious coagulation took place at the negative pole.

The decomposition of liquid albumen by voltaic electricity takes place however in very different ways according to the power employed. When the power is comparatively high the coagulation goes on rapidly at the negative pole and only slowly at the positive; whereas with an extremely low power, the coagulation is comparatively rapid at the positive surface, whilst an alkaline solution of albumen continues to surround the negative pole. It would appear also that gelatine is not precipitated by galvanic action as albumen is; which may afford an useful mode of analyzing and separating a mixture of these two fluids, and also of distinguishing a solution of albumen in alkali (such as exists in the serum of blood) from real jelly, which, when concentrated, it resembles, in having a gelatinous appearance. Thus on mixing a solution of isinglass with serum of blood and exposing the mixture to galvanic action, the albumen of the serum was first separated by this means, after which an addition of galls detected the jelly of the isinglass apparently unaltered.

Professor Berzelius in his elaborate analysis of the blood[d] (which will be further noticed under that article) finds that a solution of albumen, such as exists in the serum of blood, will readily dissolve many metallic salts particularly the suboxyds of iron. This solution is readily made, and is green when the black oxyd is used and becomes yellow by exposure

[a] Phil. Journ. vol. 11. and 14. [b] Thenard. An. Chim. tom. 67. [c] Phil. Trans. for 1809 & 1812. [d] Medico-Chirurgical Transactions, vol. 3.

to the air, with deposition of red oxyd. A mineral acid precipitates the albumen colourless and retains the iron in solution. The prussiates alone do not disturb the solution of iron in albumen, but on adding a little muriatic acid, an exquisitely beautiful blue precipitate falls down, which is a compound of Prussian blue and albumen.

The same author finds (as indeed has every other) that there appears to be very little difference between fibrin and albumen except in the mere circumstance that albumen does not coagulate spontaneously, and albumen seems to be intermediate between fibrin and the colouring matter of blood. The ash of coloured albumen is white; it contains no iron, but shews a little soda, phosphate, and carbonate of lime, and some magnesia.

The ultimate analysis of albumen when decomposed by combustion with oxymuriate of potash is thus given by Messrs. Gay Lussac and Thenard.[a] 100 parts of albumen supposed to be free from all earthy and metallic parts, contain,

Of carbon	52.883
Of oxygen and hydrogen in the proportions to constitute water	27.127
Of hydrogen in excess	4.285
Of azote	15.705
	100.000

The albumen here employed was white of egg, dried as much as possible in a boiling water heat. Sixteen grammes left after calcination in open fire 0. 976 of a gramme.

In the results of this analysis of the proportion of its elementary ingredients it is found to agree most closely with fibrin. (See *Analysis in this Appendix.*)

ALCOHOL AND ETHER.

Muriat of lime affords a still better means of bringing alcohol to the highest degree of rectification than subcarbonate of potash, or it may be used after the alkali has ceased to exert its power. Dry muriat of lime added to alcohol already highly rectified will produce two liquors, the lowest a watery solution of the salt, the highest a spirit which when carefully decanted and redistilled at a gentle heat, will afford alcohol of extreme purity and strength, the first distilled portion is the lightest and therefore the purest.

An elaborate series of experiments on the ultimate analysis of alcohol and ether, has been undertaken by Th. de Saussure,[c] in methods somewhat differing from that of Lavoisier. The operation of analysis consisted fundamently in combining the alcohol with the utmost possible quantity of oxygen, so as to reduce it entirely into carbonic acid and water, (which indeed was that of Lavoisier) and calculating from the known proportions of these substances, those of the respective constituent parts of alcohol.

Several data must be laid down as elements of these calculations, and those assumed by M. de Saussure are the following:

100. parts of water contain by weight 88. of oxygen and 12 of hydrogen, 2. parts by measure of hydrogen saturate one measure of oxygen to form water.[b]

1000. cub. inch. of hydrogen gas (Bar. 28°. Ther. 10°. Reau.) at the point of extreme dryness weigh 34.303 grs. (French weights & measures.)

1000. cub. inch. of oxygen gas under the same heat and pressure but at the term of ex- moisture weigh 512.37 grs.

1000. cub. inch. of carbonic acid, under the same circumstances as the last, weigh 693.71 grs.

Carbonic acid contains its own bulk of oxygen gas.

100. parts by weight of carbonic acid gas at the point of extreme humidity contain 26. parts of carbon.

The alcohol here used had the specific gravity of 0.792 at 16°. Reau. (68°. Fahr.) and was obtained by distilling common spirit of wine from half its weight of muriat of lime dried nearly at a red heat, and drawing off only half the liquor; and again distilling this from its own weight of muriat of lime and drawing only half.

This alcohol was burned in three different ways.

The first, (which was that of Lavoisier) was to burn it in a lamp under a receiver filled with oxygen gas.

The second, was to detonate its gasseous vapour with oxygen gas in Volta's Eudiometer.

The third, was to decompose it by passing it through a red hot porcelain tube.

The exact process of the first mode differed in some particulars from that of Lavoisier. From this the composition of 100 parts of the alcohol used was estimated as follows:

Carbon	36.890
Hydrogen	9.365
Oxygen and hydrogen as water	53.745
	100.000

[a] Recherches Physico-Chemiques, tom. 2.

[b] I. Phys. tom. 64, or Phil. Journ. vol. 21.

Of the above 53.745 of water, the oxygen is 47.296 and the hydrogen therefore is 6.449, which added to the 9.365, gives 15.814 for the entire hydrogen.

As these results differed considerably from those of Lavoisier, M. de Saussure repeated the experiment with alcohol rectified by distillation alone without addition; but after making due allowance for the proportion of water in this lower alcohol (from Richter's tables) the composition of the pure alcohol contained therein, hardly differed from the former where this alcohol alone was employed. Hence the comparative accuracy of the experiments was proved, and also the important point was proved that alcohol thus highly rectified by distillation twice from muriat of lime, does not sensibly approach to the nature of ether, as has been supposed.

The second mode of analysis was by detonating the vapour of this alcohol with oxygen in Volta's tube by the electric spark. This however would not detonate without the mixture of a little hydrogen. The fumes left after the detonation had no smell of burning spirits. After all calculations the composition of the alcohol from this experiment is:

Carbon . . .	42.82
Hydrogen . . .	15.82
Oxygen . . .	41.36
	100.00

The third mode of analysis was by passing the alcohol through a red-hot tube and examining all the products, an operation of great length and very complicated. Several foreign substances were thus detected in the alcohol, such as potash, lime, silex and acetic acid, but in very minute quantity. The *immediate* products of the whole process were a carburetted hydrogen gas, water, oil, charcoal and ashes. Of these the gas was in by far the greatest proportion, and was analyzed separately.

The composition of alcohol derived from this last process, agreed very nearly with the last mentioned, it was:

Carbon	43.65
Oxygen	37.85
Hydrogen . . .	14.95
Nitrogen . . .	3.51
Ashes	0.04
	100.00

This result however shews a small proportion of nitrogen which escaped notice in the former experiments.

Sulphuric Ether. This fluid was analyzed also by M. Theod. de Saussure, both by transmission through a red-hot porcelain tube, and by the detonation of its elastic vapour. In the former method the ether was entirely decomposed and the immediate products were a large quantity of oxycarburetted gas, amounting to near nine tenths of the weight of the ether, some oil and some charcoal deposited in the tube.

The ultimate analysis of ether gave the following results:

100 parts of ether contain

Carbon	59.
Oxygen	19
Hydrogen . . .	22
	100

Hence in equal weights ether contains much more carbon and hydrogen than alcohol, but less oxygen. The author endeavoured to ascertain what quantity of ether a determinate weight of alcohol would produce. By distilling alcohol first with sulphuric acid and then rectifying the residue by several alternate distillations from a solution of potash and fresh sulphuric acid, he obtained from 100 parts by weight of common spirit of wine, 25.25 parts of ether in the first process; 10.3 in the second; and 3.2 in the third, reckoning as part of the product the actual loss of weight during each distillation, which is here considered as etherized vapour. The sum of these products and losses of ether amounts to 38.75, which is nearly half the weight of the pure alcohol contained in the 100 parts of the common spirit of wine. These experiments, like most of the others made on these substances with a view of analysis, are confessedly only approximations to accuracy, being laborious and complicated.

Nitric Ether. An elaborate and important series of experiments on this and many other ethers has been performed by M. Thenard,[c] from the particulars of which the following description of its properties is deduced.

Nitric ether is a very inflammable, odorous, pungent liquid, somewhat lighter than alcohol, and soluble in this fluid in all proportions; almost insoluble in water, though when mixed with it giving it the smell of rennet apples; decomposable by heat and forming nitrous and acetous acid; soluble in every gas, and with

[c] Mem. d'Arcueil, tom. 1.

the nitrous and acetous acid gasses, producing a most intimate combination which can with difficulty be separated by alkalies. Nitric ether reduced to its ultimate elements is thus composed:

Azote	14.49
Carbon	28.65
Oxygen	48.52
Hydrogen	8.54
	100.00

Nitric ether is obtained by distilling equal parts of highly rectified alcohol and nitric acid. 1000. parts of the mixture give about 160 of pure ether, but for this purpose the gasseous product, which is very abundant, must be passed through five or six bottles half full of saturated brine, and cooled by ice or snow and salt, or some similar freezing mixture; and the retort itself must be frequently cooled with cold water to moderate the action of its contents. All the etherial liquors contained in the bottles must be then collected and freed from their acid, by being shaken in a bottle in contact with lime.

The gas disengaged by the first distillation is very abundant, and consists of much nitrous oxyd, a little nitrous gas, azote, nitric, acetic, and carbonic acids, together with a good deal of ether, most of which however is separated by the intense cold of the apparatus.

If the distillation is stopped when no more ether is given over, the residue contains nearly three fifths of the whole mixture, and is yellowish, acid, alcoholic, and contains nitric and acetic acids.

Nitric ether, or etherized nitrous gas, may be decomposed by potash, in the latter case by frequent agitation with a solution of the alkali, in the former by being added to an alcoholic solution of potash. After a day or two the decomposition is compleat, and the residue contains alcohol, nitrite and acetite of potash.

Muriatic Ether. The properties of this ether have also been examined by M. Thenard. Muriatic ether may be made in various ways, with more or less ease, both by distilling alcohol and the metallic muriats, and also by the direct union of muriatic acid and alcohol, as we have mentioned in the Chem. Dictionary. M. Thenard prepared it in the following way: equal volumes of alcohol and muriatic acid both highly concentrated, were put into a retort (with a few grains of sand at the bottom to avoid the spirting up of the contents when boiling) and well shaken, and then set over a furnace. A tube of safety connected the retort with a tubulated receiver, double the size of the retort, and partly filled with water so as to immerse the end of the tube. Another tube proceeded from the receiver to the first of a series of bottles also filled with water. The retort was gently heated, and bubbles of etherized gas soon appeared, mixed with some alcohol, acid, and water, all of which last were detained in the receiver, whilst the pure gasseous ether passed on in great abundance in proportion as the water became saturated with it. This gas is colourless, strongly etherial to the smell, and tastes saccharine, particularly when dissolved in water. It has no action on litmus, violets, nor lime-water. Its sp. gr. is 2.219 at 64° Fahr. (common air being 1.00) and at a medium pressure and the above temperature is soluble in its own bulk of water. It becomes liquid at 52°. Fahr. and hence the liquid ether may easily be obtained separate, by conducting the gas into an empty vessel surrounded with ice. The liquid ether also has no effect on litmus. Its specific gravity at 41°. F. is .874. When poured on the hand it immediately boils and evaporates, producing much cold. It does not congeal at —20°. F. At a medium temperature and in a short time this ether, whether gasseous or liquid, shews no trace of muriatic acid either by the action of alkalies or by nitrat of silver; but the moment that this ether is burned, so large a quantity of muriatic acid is set at liberty as to diffuse its suffocating vapour all around and to be manifested by all the proper chemical tests. It is therefore a peculiar property of this ether to contain a large quantity of muriatic acid in a state which is not readily detected except by combustion.

Muriatic ether, both liquid and gasseous, is slowly absorbed by a solution of potash in water or in alcohol, at a low temperature. At first no muriatic acid appears to combine with the alkali, but after a considerable time a little of the acid separates, though partially, and becomes sensible by the test of nitrated silver. But by raising the temperature this separation of the acid becomes much more rapid.

The sulphuric and nitric acids in like manner have but little action on the ether when cold, but decompose it rapidly when heated. On the other hand oxymuriatic gas and muriatic ether, act upon each other immediately at a common temperature, and a large quantity of muriatic acid appears.

Some experiments have been made with the same view as those above mentioned, by M. Boullay.[d] The muriatic ether was prepared in the following way. Muriatic acid gas, disengaged from dried common salt and sulphuric acid, was passed through 1000. parts of pure alcohol by a suitable apparatus, and 680 parts of the acid gas were absorbed, during which the temperature (at first 50°. F.) was raised to 75°. F. The alcohol thus saturated with muriatic acid gas was colourless, of an oily consistence, of 1.134 sp. gr., smoking when exposed to air, miscible with water, but with the disengagement of heat and bubbles of air smelling strongly of ether. This muriated alcohol was distilled separately, and the products received first into an empty bottle, kept at the temperature of 14°. to 17°. F. by muriat of lime and snow, and beyond this, into water. The distillation from the retort took place at about 86°. and most of the etherized gas condensed in the empty bottle into a liquid, which after washing with potash appeared to be pure muriatic ether.

M. Thenard states in a note (Mem. Arcueil, tom. 1. page 154) his surprize at learning that his experiments on the production of muriatic ether by muriatic acid and alcohol alone, which he considered as nearly original, had been anticipated by Basse, a chemist of Hameln, who prepared the ether by sulphuric acid, alcohol, and common salt, and by Gehlen who had repeated Basse's experiment. It appears however that Scheele discovered most of the remarkable properties of this ether, and pointed out its gasseous form, its peculiar sensible qualities, its giving no indication of acidity by litmus or nitrat of silver *before* combustion, but abundantly *afterwards*.

Muriatic ether is also made (as mentioned in the Chem. Dicty.) by distilling some of the metallic muriats or *butters* with alcohol, a process described by Scheele, Rouelle and Courtanvaux. This was repeated by Thenard with a little variation. A mixture was made in a retort of 7 parts of highly rectified alcohol and 12 parts of muriat of tin. A tubulated long-necked matrass was connected with the retort, and a Woulfe's apparatus was annexed. The matrass was empty and kept cool, the other bottles were full of water. On mixing the materials, a hissing noise like the quenching of hot iron in cold water was heard, and a very great heat was excited. The distillation was continued at a boiling heat till nearly all the alcohol was driven over. No gas whatever was generated. In the retort was left a hard yellow muriat of tin; the matrass contained two strata of liquids, the lower, which was in small quantity was a solution of muriat of tin; and the upper was a thick liquid strongly etherial and alcoholic, with a sharp metallic taste, reddening litmus, and depositing oxyd of tin on saturation with alkali. This liquid was diluted with water and redistilled, and the products were alcohol, etherized gas and muriat of tin. The etherized gas on further examination was nearly, if not absolutely, identical with the gasseous muriatic ether obtained by the former processes.

M. Thenard in a subsequent memoir gives his experiments on the ultimate analysis of muriatic ether, though confessedly imperfect. An essential part of this inquiry was to discover the proportion of muriatic acid, or its elements, combined in the ether. For this purpose a given quantity of muriatic acid and alcohol were put into a retort and distilled, with proper precautions to collect all the products, liquid and gasseous, and these were afterwards separately examined. The quantity of muriatic acid entering into the composition of the ether was estimated by comparing the quantity of potash required to saturate the acid in the retort before and after the distillation, all the loss of acid from the retort being supposed to enter into the composition of the ether. From these data it would appear that muriatic ether contains full 30 per cent. of its weight of muriatic acid of an equal degree of concentration as exists in fused muriat of potash.

Action of Oxymuriatic Acid upon Alcohol.

The mutual action of these two substances was first examined by Scheele, and afterwards by Berthollet, Pelletier, and other chemists. They have noticed the production of a green oil in the process, and of a quantity of ether. M. Thenard in repeating this experiment employed 300 parts of alcohol, and passed through it the oxymuriatic gas arising from 1750 parts of common salt, 450 of black oxyd of manganese, and 800 parts of sulphuric acid diluted with as much water. The gas was first washed by transmission through water, and then sent into the alcohol, and the whole was absorbed. The liquor contained a greenish-white oil, and a great excess of muriatic acid. On rectification with alkali no ether was obtained, but only an alcoholic liquor holding more of

[d] An. Chim. tom. 63.

the same oil in solution. This in some respect agrees with the result of Dollfuss's experiments before mentioned;[e] so that it seems still doubtful whether true muriatic ether is formed by the mere transmission of oxymuriatic acid through alcohol.

Phosphoric Ether.

The following process is given by M. Boullay[f] for the preparation of phosphoric ether, the existence of which had been doubted by several chemists. To a tubulated retort placed on a sand-bath was joined a tubulated receiver connected with a Woulfe's bottle full of lime water and with a pneumatic apparatus. Into the retort were put 500 grammes of pure phosphoric acid, made by acidifying phosphorus by nitric acid, vitrifying the acid, redissolving and evaporating it to the consistence of honey. A glass vessel similar to the *Acid-Holder*, open at both ends and terminating at one end in a long tube with a stop cock, was fitted to the tubulure of the retort, the lengthened tube dipping into the phosphoric acid. The receiver being kept cool by a mixture of salt and ice, the acid in the retort was heated to about 215°. Fahr. Then 500 grammes of alcohol were let down, drop by drop, into the heated phosphoric acid. A violent ebullition took place on the mixture, which turned black, and numerous streaks of condensed vapour immediately appeared on the neck of the retort. The fire was kept up till the contents of the retort were dry.

There passed into the receiver,

1st. 120 grammes of weakly etherized alcohol.

2d. 260 grammes of a clear, light liquid, smelling much more strongly etherized than the last.

3d. 60 grammes of water saturated with ether, on which floated about four grammes of a yellow empyreumatic liquid resembling oil of wine.

4th. Another liquid insupportably fetid, reddening litmus and effervescing with carbonat of potash. When saturated with this alkali it afforded acetite of potash.

The lime water became turbid only at the end of the distillation.

The gas collected had a sweet penetrating smell, burning with a white flame and depositing a copious black soot.

The two first products of the distillation being mixed and rectified by gentle distillation from muriat of lime, gave 60 grammes of a very pure ether strongly resembling sulphuric ether, in its partial solubility in water, rapid evaporation in the air, burning with a white flame and smoke, and leaving no marks of acidity when kindled on the surface of water.

Alcohol and the Vegetable Acids.

Most of the vegetable acids dissolve in alcohol, but the spirit is separable again by distillation in an unaltered state from all but the acetic acid, and even this latter will not convert alcohol into ether without frequent cohobation, or the use of some of the dry acetites.

But if a small portion of any of the concentrated mineral acids be added to the vegetable acid and alcohol before distillation, a most striking difference of result is observed. The alcohol is changed more or less compleatly into an ether or a substance resembling ether, consisting of an intimate combination of the alcohol and acid, which hardly if at all shews any acid properties before combustion, but gives a large quantity of acid afterwards. This curious subject was first undertaken by Scheele, who shewed by experiment the facility with which the addition of a little muriatic acid promotes the separation of acetic ether from acetic acid and alcohol, and observed a singular product obtained in this method from benzoic acid, muriatic acid and alcohol, but failed in procuring any particular results from the tartaric, citric, boracic and succinic acids. This subject has also been examined with some minuteness by M. Thenard.[g]

Some of the experiments we shall mention.

Benzoic Acid, Alcohol and Muriatic Acid.

30 parts of benzoic acid, 60 of alcohol, and 15 of concentrated muriatic acid, were distilled till two thirds of the ingredients had passed over. No gas but common air appeared, and scarcely a trace of muriatic ether. The first distilled product was only alcohol, but afterwards a peculiar matter came over dissolved in the spirit but separable by water. The retort also contained much of the same substance which had congealed to the bottom. It was separated from all the other matters by washing with hot water in which itself was hardly soluble. This substance was yellowish, pungent, somewhat heavier than water, fusible at from 76°. to 86°. F. and volatile at about 176°. F. it was acid, oleaginous, nearly insoluble in cold water, but considerably soluble in hot water and in alcohol, from which last it was precipitable by water. When the excess of

[e] Chem. Dict. article *Ether*. [f] An. Chim. tom. 62, p. 192. [g] Mem. Arcueil. tom. 2.

acid was saturated with an alkali it still remained white, pungent, and odorous, and quite liquid at a common temperature. When long agitated with liquid potash it gradually was absorbed without the disengagement of any gas, and appeared to be resolved into alcohol and benzoic acid, but no muriatic, and yet it cannot be formed by the direct distillation of benzoic acid and alcohol, without the intervention of the muriatic acid.

The citric, oxalic, and malic acids, distilled with alcohol and a little sulphuric acid, all gave a peculiar substance somewhat resembling that from the benzoic acid.

Acetic Ether. 20 parts of acetic acid congealable at 32°. F. were distilled once with 30 parts of alcohol of .800 sp. gr. It required much heat to bring the mixture to boiling, and only a very little acetic ether was produced.

The same experiment was repeated with the addition of 5 parts of strong sulphuric acid: 19 parts of the acetic acid disappeared, the ether was produced with singular ease and almost without heat, and as much as 40 parts were obtained: this appears to be a very simple and excellent process, and the ether may be rectified easily by a little potash even without a second distillation.

Acetic ether may also be made very well by Scheele's method, *(Chem. Dict. art. Ether.)* The following are given by M. Thenard as good proportions: 3 parts of acetate of potash, 3 parts of strong alcohol, and 2 parts of concentrated sulphuric acid, distilled to dryness. The product again slowly distilled with a fifth of its weight of fresh sulphuric acid, will give as much rectified acetic ether as the alcohol employed. The sulphuric acid should be always concentrated. Any other neutral acetite will answer the same purpose, and the dose of sulphuric acid should be somewhat more than will saturate the base of the acetite. The neutral acetites distilled *per se* yield a peculiar substance called *Pyro-Acetic Spirit*, already described in the article *Acetic Acid* in this appendix. M. Thenard infers as a general law, from these and other experiments, that when the vegetable acids are pure, none of them, except the acetic, will combine with alcohol in such a way as to lose their acid properties; but when a mineral acid capable of strongly condensing alcohol is added, all these vegetable acids acquire the property of uniting with alcohol into a peculiar compound which shews no acidity till the compound is again decomposed by heat or alkalies, and which does not contain any of the mineral acid necessary to its formation.

Alcohol—how produced from fermented liquors.

In our original article *(Fermentation, vol. 1. p. 431)* we mentioned that a question has arisen whether alcohol exists ready formed in fermented liquors, or whether it is a product generated from them by the act of distillation. Mr. Brande has given some experiments on this subject in which he favours the former opinion.[a] Fabbroni who advanced the latter of these two opinions, asserts that though dry carbonat of potash will not separate any alcohol from wine in its natural state, yet if as little as a hundredth part of alcohol is purposely added to wine, this addition will be made apparent by mixing dry subcarbonate of potash to the wine. Mr. Brande however did not find this to be the case with the wines which he employed; for when 4 oz. of the dry alkali were added to 8 oz. of port wine, both pure, and mixed with $\frac{1}{8}$ of alcohol, no separation of spirit took place in either instance, but the mixture in both cases divided itself into two portions, the lower of which was a saturated solution of the alkali, and the upper was a gelatinous mass containing apparently all the colour and extract of the wine, uniformly and undistinguishably mixed with the spirit. Nevertheless as it was found that very exactly the same proportion of alcohol was yielded by pure wine, when distilled at different temperatures, (the boiling point being raised artificially in some of the experiments by adding muriat of lime) the author conceives that this is a sufficient proof that the alcohol is not *formed* but merely *expelled* from the wine by distillation, since if it had been actually formed in the process, he supposes that a change in the boiling temperature must have influenced the product of alcohol in one way or other.

A much more satisfactory proof of this opinion with regard to the formation of alcohol is however furnished by the same chemist in his last paper, in which he first precipitates all the extractive and colouring matter from wine by the subacetate of lead, and *then* the addition of the alkali separates the alcohol from the wine thus clarified in a very distinct manner. One measure of a saturated solution of the salt of lead added to 8 measures of port wine, and shaken for a few minutes and thrown on a filter, gave a perfectly clear and colourless

[a] Phil. Trans. for 1811 & 1813.

liquid, from which on the addition of dry subcarbonat of potash the alcohol separated rapidly. Mr. Brande found by experiments with alcohol and coloured water, that this mode separated the spirit almost totally from the mixture, whence it is reasonable to infer that no spirit whatever is generated by distillation, but only expelled from the fermented liquor.

The subacetate of lead is prepared by boiling two parts of sugar of lead with one of finely powdered litharge, in six parts of water. It should be kept carefully excluded from the air which is constantly converting it to insoluble carbonat of lead. The effect of this subacetate in separating all vegetable matter from infusions of vegetables has been long noticed by Dr. Bostock and other experimental chemists.

ALCOHOL OF SULPHUR. See SULPHUR, ALCOHOL OF.

ALKALI (FIXED.)

Potash and soda prepared from the carbonats of these alkalies by lime, the caustic alkaline solution being evaporated to dryness, redissolved in alcohol, and again dried and heated to redness, have long been considered as being in as high a state of purity as can be produced by chemical means. *See the Article (Potash) Chem. Dict. Vol. II.*

But a most important discovery has lately been made which affects the results of all the analyses of the neutral salts with a basis of potash or soda, and indeed is peculiarly satisfactory, as it explains the anomaly, before unaccountable, of the great difference in the estimation of these salts when the experiments are made with the dry alkaline carbonats or the dry caustic alkali. The discovery is, that the caustic fixed alkali prepared with the utmost care and brought to a state of fusion in a red heat, is not the simple alkali, but contains a considerable proportion of *Water*, which cannot be expelled by any length of fusion, though it does not accompany the alkali when neutralized with an acid and again brought to the heat of ignition. Hence if in any analytical experiment a given weight of ignited caustic alkali is saturated with an acid, and the entire neutral salt thence resulting is ignited and weighed, it is obvious that if the caustic alkali employed be considered as mere alkali, the proportion of alkali in the neutral salt will be much overrated, and therefore the quantity of acid required to saturate 100 parts of the alkali will be estimated much lower than the truth.

This anomaly was very accurately stated and its real cause suggested by M. Darcet, in a Memoir read at the French Institute, January, 1808.[a] The experiments of this eminent chemist are (in a few words) the following:— Some very pure subcarbonat of soda was prepared and saturated with a dilute sulphuric acid, containing exactly a tenth part of pure concentrated sulphuric acid of 1.844 sp. gr. This subcarbonat was found by various analyses to consist of 63.61 of water: 16.04 of carbonic acid, and 20.35 of soda. A hundred grammes of this subcarbonat were exactly saturated by 347 grammes of the dilute sulphuric acid, equal to 34.7 of the concentrated acid; which would give 170.55 of the concentrated acid to saturate 100. of the mere soda in the state in which it exists in the carbonat. On the other hand 100. grammes of caustic soda prepared by alcohol and fused in a silver vessel at a red heat, saturated only 119.6 grammes of the sulphuric acid in one experiment, and 122.4 in another, making a difference of about 50 grammes of acid in the estimated quantity in the two cases. Hence it must follow that the soda prepared by alcohol contains only 71 72 per cent. of real alkali in that state in which it exists in the carbonat, both salts being equally ignited, and therefore that which has usually been considered as pure soda, is properly *Hydrat of Soda*, consisting of about 72 of pure soda and 28 of water.

The next experiments on this subject which we shall mention are those of M. Berthollet[b] This eminent philosopher in his Researches on the Laws of Chemical Affinity, has taken much pains to determine the respective quantities of most of the acids and bases that saturate each other, and in this enquiry the composition of sulphat of barytes came under particular consideration, as it is a salt very commonly obtained in analytical experiments, and its insolubility renders it a very convenient basis of calculation.

It would appear at first to be a problem of no great difficulty to determine the elements of this salt, and yet the calculations of equally skilful and accurate chemists varied as much as to give a difference of from 67 to 75 per cent. in the proportion of acid, which is much too great to be accounted for from any of the common inaccuracies in chemical experiment.

On further examination M. Berthollet found the cause of this difference to be in the barytes used. He and M. Thenard employed barytes crystallized from its aqueous solution, evaporated to dryness, and strongly ignited. M.

[a] An. Chim. tom. 68.

[b] Mem. d'Arcueil, tom. 2. p. 50

Berthier, Richter, Bucholz, and other equally distinguished chemists used the barytes prepared from the nitrat of barytes by a strong heat, which destroys the acid and leaves the barytes pure. In the first instance the barytes was more easily fusible than the other, and when cold had the appearance of a semi-transparent glass. The barytes from the nitrat on the other hand required a much greater heat for its fusion, and in melting absorbed a little carbonic acid. By adding a little water to this barytes it became in every respect like the other. The barytes from the watery solution of this earth, was also strongly heated with iron filings in a porcelain retort, and gave out a large quantity of hydrogen. From these facts the author shews that the barytes from the aqueous solution is a *Hydrat* of Barytes, containing about 10 per cent. of water, and the purer form of barytes is that which arises from the calcination of the nitrat.

This discovery led the author to suspect that potash might retain water when heated *per se*, and give it up when it enters into saline combinations. The principal experiment is the following: Some potash was melted in a silver crucible whose weight was known, and kept in fusion till it exhaled white vapours, when the cover was lifted off. The crucible with its contents was weighed when cool, and 15.73 grammes of fused alkali were found to be contained in it. This was dissolved in muriatic acid, and the whole solution with the washings was carefully evaporated and ignited in a platina crucible, till the muriat of potash was in perfect fusion. When cold, the muriat of potash weighed 20.335 grammes, and produced with nitrat of silver 38.586 gr. of well dried luna cornea, which (reckoning 17.5 per cent. of muriatic acid in luna cornea) indicated 6.752 gr. of acid. Consequently the 20.335 of fused muriat of potash consisted of 6.752 of muriatic acid and 13.583 of potash; but 15.73 of fused caustic potash was employed, and hence the difference between 15.73 and 13.583 (2.147) is the quantity of water contained in the fused caustic potash, which gives the proportion of 13.64 of water in 100. of fused potash.

The existence of a large quantity of water of composition in fused potash is also shewn by heating the alkali strongly with iron filings in a porcelain retort, by which a prodigious quantity of hydrogen gas is given out.

It appears however that though fused potash gives up a large quantity of its water of composition when neutralized by an acid, yet some water is still retained, at least by one or other of the component parts of the compound, for most saline bodies will give hydrogen when heated strongly with iron filings.

Messrs. Gay-Lussac and Thenard,[c] have also made several experiments to determine the quantity of water contained in fused caustic alkali prepared with alcohol. A portion of fused potash was carefully weighed in a closed vessel, it was then taken out, put upon a dish of platina, and introduced into a large glass globe nearly full of a measured quantity of carbonic acid, standing over mercury, so that the alkali did not touch any portion of the glass. The alkali was then heated very gradually, when it became white on its surface, softened, rapidly absorbed the carbonic acid gas, and in so doing such a quantity of water was disengaged as to trickle down the sides of the glass globe. The heat was very gradually raised to a cherry red. The water was then absorbed by blotting paper, and the remaining carbonic acid gas measured, and the carbonat of potash weighed.

A similar experiment was performed on fused soda.

The results of these were, that 100 parts of fused potash in combining with carbonic acid, give up 13.596 parts of water; and 100 parts of fused soda give up 22.166.

The next experiment was to combine the alkali with silex by fusion, forming a glass. A given weight of the fused alkali and ignited silex were put into a silver crucible, and some water added to promote an entire mixture of the ingredients, which was then slowly dried and ignited to redness for an hour. The result was a perfect glass, which was weighed. From this experiment, 100. parts of fused potash were found to contain 18.45 of water of composition, and 100. parts of fused soda contain 26.15 of water.

The third experiment was the following: A certain weight of fused potash and of fused soda were saturated with sulphuric acid and the quantity noted. On the other hand known quantities of potassium and sodium were exposed to a moist air in long narrow vessels, till they were converted into their respective alkalies, which were then saturated with the same sulphuric acid as that employed before. Hence supposing the alkali produced from the potassium and sodium to be pure, and free

[c] Recherches Physico-Chimiques, tom. 2.

from water of composition, and knowing the quantity of alkali produced by the alkaline basis, it was easy to compare the saturating powers of these alkalies with those of the fused potash and soda prepared by alcohol. From these data 100 parts of fused potash prepared by alcohol contain 20.72 of water of composition: and 100 parts of fused soda contain 23.89 of water.

The authors take as a mean from these experiments (rejecting the first as far as regards the potash as being imperfect) that caustic potash, prepared in the common way by alcohol, and fused at a red heat, contains a fifth of its weight of water; and fused soda a fourth.

We may observe however that these results differ much too widely to be a fair subject for taking an average, except in a very general way. Perhaps, too, it is impossible to fix precisely the quantity of water contained in the fused caustic alkali, as this may vary according to the heat employed and other circumstances. It shews however that this form of alkali is certainly a *Hydrat*, or one that contains a notable quantity of water of composition, and also that no great dependance is to be placed on the accuracy of any calculation on the proportions of the alkaline neutral salts, which is founded on the quantities of the Hydrated Alkali employed.

ALKALINE BASIS. Potassium. Sodium.

One of the most interesting discoveries of modern chemistry is the decomposition of the fixed alkalies which had often been conjectured to be of a compound nature, but no evidence of the truth of this opinion had ever been given till Sir H. Davy applied to this enquiry the astonishing powers of electro-chemical agency. The researches which he had made on the decomposition of acids and neutral salts by galvanic electricity were full of new and most interesting results, they pointed out a mode of chemical analysis far more powerful than any that had been hitherto undertaken, and the admirable skill in contriving experiments, and sagacity in deducing from them the general laws of chemical decomposition, enabled him to make the brilliant discovery which is the subject of this article. He conjectured that if a freed alkali was an oxyd of some unknown base, it was probable that when it was subjected to the action of opposite electricities, the oxygen of the alkali would be conveyed to the positive pole, whilst the inflammable base would appear in a separate state at the negative pole.

Some difficulties arose at first in selecting a proper mode of conducting the [illegible]. When a solution of the alkali was [illegible] electric power was expended chiefly [illegible] composition of the water present; as [illegible] other hand, when the alkali was dry [illegible] at the time of applying the electric [illegible], it was indeed decomposed, but the basis instantly burnt with a most intense light and flame, and could not be collected. The great difficulty in the experiment was that the alkali, when dried and fused, is a non-conductor of electricity; but it was found that slightly moistening the surface renders it a conductor, and in this state it readily fuses and is decomposed by strong electrical powers.

The basis of potash was thus discovered.* A small piece of potash which had been exposed for a few seconds to the atmosphere, so as to give conducting powers to the surface, was placed upon an insulated disk of platina, connected with the negative side of the galvanic battery in intense activity, and a platina wire communicating with the positive side was brought into contact with the upper surface of the alkali. A vivid action soon took place. The potash began to fuse at both points of contact; there was a violent effervescence at the positive surface, and at the negative there was no liberation of elastic fluid, but small globules having a high metallic lustre, exactly resembling quicksilver in appearance, were formed, some of which immediately after burnt with explosion and bright flame, while others remained being first tarnished, and finally covered by a white film on their surfaces. The gas liberated at the positive surface was found to be pure oxygen, and the globules were found by numerous experiments to be a peculiar inflammable principle, the *Basis of Potash*. The platina was in no way connected with the result except as a medium for the electric power, for the same effects were produced by substituting copper, gold, plumbago or charcoal.

Soda when acted on in the same manner gave a similar result, but it required a greater intensity of galvanic action to produce the *Basis of Soda*. With a good battery of 100 6-inch plates, the Basis of Potash could be obtained from pieces of the alkali weighing 40 or 50 grains, which made the distance between the opposite wires nearly ¼ of an inch; but with the same galvanic power, pieces of soda

* Phil. Trans. for 1808.

not exceeding 15 or 20 grains could be used, making the distance between the electric poles not more than $\frac{1}{8}$ or $\frac{1}{10}$ of an inch.

The Basis of Potash has been named by the discoverer POTASSIUM, and the Basis of Soda, SODIUM, which term has been universally adopted.

The principal properties of POTASSIUM discovered by Sir H. Davy in his first series of experiments, are the following.

When exposed to the air a white crust rapidly collects on the surface, tarnishing its metallic lustre, and this continues to be produced till the whole is converted to this white crust, which is found to be pure potash. When globules of Potassium are confined in common air, or especially in oxygen, at a common temperature, the same crust is formed, but not being removed by deliquescence, the process is stopped, the interior part of the globule being protected by the crust of regenerated alkali from further change. But when the temperature is raised highly, a rapid and brilliant combustion takes place, and the whole is changed to solid dry potash. Oxygen gas alone is absorbed in this change, the azotic admixture being in no degree affected, and the weight of the potash considerably exceeds that of the potassium decomposed.

Potassium is a soft and malleable solid of the lustre of polished silver at 50° Fahr., at 32° it it is hard, brittle, and exhibits in its fractured surface beautiful facets of a perfect metallic whiteness. At 60° it begins to soften and become pasty, and at 100° it is perfectly fluid, so that the globules will run together. At a red heat it is converted into vapour, but in close vessels it condenses unaltered on cooling.

It is a very perfect conductor both of heat and electricity.

One of the most remarkable circumstances relating to potassium is its very great levity. Though resembling the metals in outward appearance, in opacity and lustre, it is not only lighter than any of them, but even than water, ether, naphtha, or almost any known fluid. The exact determination of its specific gravity is attended with difficulty, but Sir H. Davy estimates it at about 0.6 (water being 1.)

The action of water upon potassium is very striking. When a globule of it is touched with a drop of water, it instantly burns with a bright flame and a solution of potash is left. If this simple experiment be performed on paper tinged yellow with turmeric, the spot where the combustion and generation of alkali takes place is strongly marked by a deep brick-red stain. When potassium is decomposed by water in close vessels, a gas is found among the products, which is pure hydrogen. So strong is the affinity of potassium for oxygen, that it decomposes water wherever it exists, and thus discovers the watery admixture in the purest alcohol and ether, in both of which the potassium produces potash and hydrogen gas.

In the liquid acids potassium is immediately decomposed. In the sulphuric it produces at once a white salt (probably sulphat of potash) with a yellow coating, which appears to be sulphur. In the nitric and muriatic acids it produces nitrat and muriat of potash.

As potassium cannot exist for a moment unaltered in water or any fluid containing water, nor for any length of time in air, it was a matter of difficulty to find some mode of preserving it. It was found however that naphtha recently distilled will preserve it unchanged for a sufficient length of time, though even in this fluid it gradually oxydates and forms a kind of potash soap with the naphtha, that collects round the globule and prevents it from floating in this fluid. It also slowly forms an alkaline soap when confined in any of the oils.

Potassium unites with many of the metals with great ease, forming very peculiar alloys. It amalgamates readily with mercury and remarkably reduces its fluidity; for when united with 30 times its weight of mercury, the alloy is hard and brittle. The fluid amalgam dissolves all the metals, forming a triple alloy of mercury, potassium and the other metal employed. When the amalgam is thrown into water, a hissing noise is produced, hydrogen gas is given out, potash is generated, and the mercury returns unaltered to its original state.

Potassium will equally well unite with gold, silver and copper, and it is equally separable from these alloys by mere moisture, which regenerates the alkali.

Potassium readily reduces many of the metallic oxyds, and when in excess it unites with the metal thus reduced.

It decomposes the metallic oxyds in flint-glass and green-glass at a low red-heat; but it also gradually changes perfectly unmetallic glass when heated in such vessels, slowly alkalizing itself and corroding the glass.

These are the principal properties of this singular substance as given by the illustrious discoverer in his first memoir on the subject, by which it appears that potassium has by far the strongest affinity for oxygen of any hitherto

known substance, and this renders it a most valuable reagent for a variety of interesting chemical decompositions.

Before we proceed with the other properties of potassium we shall describe another method of procuring this substance without the assistance of any galvanic apparatus, and in much larger quantity. This method was found out by Messrs. Gay Lussac and Thenard, soon after Mr. Davy's original discovery of potassium, and is described by them with much minuteness.[b] It consists in heating iron filings to great intensity in an iron gun-barrel, and then passing melted potash through them. The potash is decomposed, a large quantity of hydrogen gas is given out, and the potassium is condensed at the further extremity of the apparatus. As this, though not very complicated, requires a good many precautions, we shall give the original process with minuteness.

The materials. Iron turnings are preferable to iron wire or nails, as they present a considerable surface and yet allow the alkali to pass freely through them. They should be broken down in a mortar, and any adhering oxyd sifted away. The choice of the alkali is not a matter of indifference. The common potash or pearlash always contains a small portion of soda, and hence the caustic potash prepared from it is mixed with a little soda, which causes an alloy of a small quantity of sodium with the potassium obtained. Therefore in delicate experiments of research the potash should be prepared from pure crystallized nitre and cream of tartar ignited together, or from calcined cream of tartar alone, which gives the purest potash known. The alkali should be made caustic with lime in the way mentioned under the article *potash*, (Ch. Dict.) and indeed the extraction of the alkali by alcohol is hardly required, but it should be kept at a red heat for some time just before being used, as the presence of much moisture defeats the object of decomposition of the alkali.

The apparatus consists of a gun-barrel A.B. C. (see plate, fig. 1 and 2.) which should be well cleaned within and then bent in two directions by being heated red-hot at the parts required. The middle of the barrel B.C. which is enclosed in the furnace, must be well covered with a very refractory lute, as it is to undergo a very intense heat for a considerable time, which would soon oxydate and destroy the barrel without such protection. The best lute is a mixture of pipe clay (or Windsor loam) beat up with a little water, and incorporated with as much sand as possible so as to make it difficult to apply. The only part to be luted is that which lies across the furnace, and to this the lute is to be applied in three or four successive thin coatings, and dried with great care, first for a few days in the shade, and then with a gradual heat, filling up any little cracks in it by some fresh lute. The gun-barrel is then filled with the iron turnings, as far as from B. to C. and is then firmly fixed in the furnace, and afterwards the fragments of recently heated potash are put in, without being much pressed, so as to reach not quite to B. and up to a few inches below A. This requires generally about 3 ounces troy, more or less. As much gas always issues through the other extremity D, to prevent any mischief or loss of potassium when accidentally stopped up, it is of use to adopt a bent glass tube to the upper end of the barrel A. which dips under mercury M. as seen in the plate, fig. 1. and allows of the reflux of any gas from the barrel if necessary.

The apparatus being then put up, a fire is lit in the furnace, and the bellows applied, at first very gradually, to prevent the lute from cracking. The recipient G. H. is formed of two copper tubes fitted to each other by grinding, the uppermost of them receiving the end D. of the gun-barrel. A glass tube F. fits into the lower half of the recipient and dips into mercury. The recipient is luted on to the gun-barrel by the same fire-lute. When the fire is well kindled the bellows are to be used vigorously, and the heat raised to a very high degree at the same time that the ends of the barrel that project beyond the fire above and below, are kept cool by wetted cloths. When the fire has been raised to its utmost for some time, the wet cloths are removed only from the upper end of the barrel that contains the potash, and instead of it either a small furnace, or chafing dish or hanging trough of iron, E. filled with hot charcoal, is to be applied so as to cover the lower part of that portion of the barrel that contains the potash, and to melt the alkali, which requires a moderate red heat. The melted alkali then falls down into the lower part of the barrel, which is intensely heated, and passes in the form of vapour through the iron turnings. At first the water which the alkali contains in abundance (though previously fused)

[b] Recherches Physico-Chimiques, tom. 1.

decomposes upon the iron turnings, and much turbid hydrogen gas comes over. At the same time however the potassium is produced and is also vaporized within the furnace, but immediately condenses, partly in the extremity of the barrel, D. and partly in the copper recipient, both which are, as before, kept cool by wetted cloths. When the efflux of gas begins to slacken, an additional portion of potash is sent down, by shifting the hanging trough of charcoal a little higher, and so on till the whole has been heated almost to the extremity A. It is of importance not to send over too much alkali at once, as this would damp the heat of the iron turnings, and lessen the product of potassium, and this too is one reason why the potash is put in in large pieces. It is a sign that the operation is going on well when the product of hydrogen at the lower extremity is pretty steady and abundant, but not very cloudy. The distillation is terminated when all the alkali has been successively melted down, which takes about an hour from the time that the gun-barrel is first made white-hot, and it then only remains to collect the product, which requires a little dexterity and caution.

The potassium being volatile condenses for the most part in the end of the barrel at D. and thence falls down into the copper recipient G. H. where it solidifies. To collect it, remove the barrel when the distillation is over, stop the upper end A. with a little lute, and hasten the cooling of the barrel by stripping off the lute and wetting the outside, then pull off the copper recipient (immediately stopping the end D. of the gun-barrel that is thus exposed) separate it into its two parts, pour into each a little naphtha, and detach all the potassium with a knife, throwing it into a bottle of naphtha as soon as separated. As some of the potassium remains in the end of the gun-barrel nearest to the recipient, it is the best way to cut off that end with a file, (as the barrel will never serve for a second operation) and to push out all the potassium into oil with a solid mould made for the purpose. This is generally mixed with a little potash from which it may be freed by melting in oil and pressing the whole.

The product of two experiments is given by the authors, in which it appears, that in one, 70 grammes (about 18 drams troy) of potash was employed of which nearly $\frac{4}{7}$ths was recovered undecomposed from the iron turnings, and the product of potassium was 15.5 grammes (231 grains troy.) In the other experiment 81. grammes of potash were used, and the product of potassium was 20. 2 grammes or nearly a third more than in the former case.

Sometimes the efflux of hydrogen gas from the lower part of the barrel ceases suddenly, and appears at the upper extremity. This may be owing to the stoppage of the end D. by a collection of condensed potash, when the fire has not been kept hot enough or when the alkali has been sent down too fast. This may sometimes be removed by heating the tube with charcoal on the outside, and melting away the obstruction. But if no gas is sent out from either end, it generally shews that the barrel has partly fused down owing to some imperfection in the lute, in which case the process must be discontinued and renewed afterwards either with a fresh barrel or better luting. If a very large barrel is used, a fresh charge of potash may be thrown into the upper part, and the process kept up for an additional time provided enough of iron turnings are introduced at first.

After the operation, if the gun-barrel is divided in different parts where it has been exposed to the furnace, it is found to contain a very hard agglutinated mass of alkali, oxyd of iron, alloy of iron and potassium, and unaltered iron turnings, which require considerable digestion in water to dissolve out the alkali. The quantity of alkali recovered from the iron, is full half of what has been used, and yet a large portion of the iron turnings retain their metallic appearance and their form, so that there is probably much loss of potassium by its alloy with part of the iron, which returns to the state of potash when moistened.

It may be of some assistance to the chemical operator to give Dr. Henry's very clear directions for preparing potassium, according to a process just described, but with some little variation in the apparatus.*

The apparatus consists of a common gun-barrel, curved and drawn out at one end to rather a small diameter, (see plate, fig. 3). To one end is adapted an iron tube *a.* with an iron stopper) of the capacity of two cubic inches, for containing the potash. At the bottom of this tube is a small hole *h* through which the potash gradually flows. This tube is shewn separately in fig. 4. To the opposite end of the gun-barrel a tube of safety *e* is to be cemented; and into this a sufficient quantity poured either of mercury or naphtha. Into the gun-barrel $2\frac{1}{2}$ parts of very clean iron turnings

* Elements of experimental Chemistry, 6th. edition, vol. 1.

are to be introduced and pushed on to the bent part *c*. The tube, carefully luted is then to be placed in a small furnace, nine or ten inches in diameter, and provided with a pair of double blast bellows, the pipe from which is shown at *f*. The next step is to insert the tube *a* in its place, after having put into it $1\frac{1}{4}$ parts of pure potash recently fused. The whole apparatus should be perfectly clean, dry, and impervious to air. A strong heat is now to be excited in the furnace, and while this is doing, the tube containing the potash as well as the opposite end of the barrel should be kept cool by ice. When the barrel has attained a white heat the potash in *a* may be melted by a small portable furnace. It will then flow by the small hole upon the iron turnings. Much hydrogen gas will be evolved, and when this slackens we may remove the small furnace from beneath the tube *a* and increase the heat in the furnace *d*, in order to restore to the iron turnings at *c*, the temperature proper for decomposing more potash. These operations may be repeated alternately till no more gas is produced, but last of all the heat in the furnace should be strongly raised to drive off some of the potassium that adheres strongly to the iron turnings.

When the furnace is quite cold, the safety-tube *e* is to be removed, and its place supplied by an iron plug. If the end of the gun-barrel projecting from this side of the furnace has been kept carefully cooled during the experiment the metal will be found adhering to it in the form of brilliant laminæ. In order to extract it, the gun-barrel is to be cut off at the beginning of the part that has been kept cool, where the greatest quantity will be found. Another portion will be found close to the plug, and this adheres so slightly to the gun-barrel that the least effort serves to detach it. It is even partly oxidated by the air that enters on cooling the furnace, and when the whole is covered with naphtha the oxidized part is detached in laminæ, exposing a white and brilliant metallic surface. The potassium which is condensed nearest the furnace must be separated by a sharp chissel in the largest pieces we can possibly break off. In the middle of the gun-barrel we shall find an alloy of potassium and iron which becomes green on exposure to the air, the potassium returning to the state of potash.

The potassium prepared in this way if the alkali is pure hardly differs from that obtained by galvanic electricity, except that its specific gravity is somewhat higher, being to that of water as 796. to 1000.

Having already described the leading properties of potassium as first observed by Sir H. Davy, we shall proceed to give an abstract of a very long and minute series of experiments on the same subject carried on by Messrs. Gay Lussac, and Thenard,[a] most of which furnish results very nearly similar to those of the eminent discoverer of the alkaline metals, but others are different and throw new light on the nature of these curious bodies.

Action of Water on Potassium. When a little water is confined in a jar over mercury, and a portion of potassium is passed up (enclosed in paper) the potassium swims on the water, moves about and lessens rapidly, and soon disappears, leaving the water very alkaline, and a considerable quantity of hydrogen gas is produced. When this experiment is performed, merely by throwing some pieces of potassium on water they soon become red hot while decomposing on its surface, which forms an amusing experiment. To determine the exact proportion of hydrogen produced by the conversion of potassium into potash by means of water, a small iron tube was filled with 2.213 grammes of potassium, and covered with a glass plate, and thus introduced under a bell-glass full of water. The decomposition took place with great rapidity, and, when complete, the hydrogen was measured and found to be 0.666 litre at 15° centigrade therm. and 0.7455 metre bar. The experiment was repeated with the same result, whence it follows that 100 parts by weight of potassium absorb 19.943 parts of oxygen to pass to the state of potash; and hence 100. parts of potash consist of 83.371 of potassium, and 16.629 of oxygen. These proportions closely correspond with those given by Davy and Berzelius.[b]

Messrs. Gay Lussac, and Thenard give a simple method of dividing potassium into equal portions without the trouble and loss attending the process of weighing this decomposable substance, namely, by compressing it into a cavity made in a small block of brass, on which another block exactly fits so as to exclude every atom of potassium except that which fills the cavity. The quantity of hydrogen given by this portion of potassium in ten different experiments varied only from 78.5 to 79.4 measures, and hence assuming 79. as the average, and comparing this result with the former above mentioned

[a] Recherches.   [b] Ann. Chim. Tom. 80. p. 245.

(in which 2.213 grammes of potassium gave .666 litre of hydrogen) the weight of the portion of potassium filling the cavity in the brass was pretty exactly estimated at 0.0212 gramme. This quantity was therefore the standard of all the subsequent experiments.

Potassium and Oxygen. If potassium is confined in contact with oxygen at a common temperature and kept at rest for some days, it gradually loses its metallic appearance, and is converted entirely into a grey substance. But if the temperature is a little raised or the surface of the metal renewed, it takes fire and the combustion goes on rapidly.

Oxyds of Potassium. There are certainly two distinct oxyds of potassium, and probably three, namely, the suboxyd, the alkali, and the peroxyd.

The suboxyd is a bluish-grey very brittle substance, softer than wax, easily fusible, so inflammable as to take fire in oxygen or even in common air at about 70° Fahr. decomposable by water into alkali, and giving out hydrogen like potassium but in smaller quantity. It is therefore in a lower state of oxydation than the alkali. This suboxyd is produced by confining potassium for some days in an empty phial closed with a cork, the pores of which admit such a very gradual supply of air and moisture as suits the slow and inferior state of oxydation required. It appears however doubtful whether this suboxyd may not be a mixture of potassium and potash, and it has certainly not been obtained sufficiently uniform to allow of its precise degree of oxydation to be well ascertained.[c]

The second oxyd of potassium is the alkali itself, the composition of which has already been mentioned. This oxyd, the alkali, is always produced, whenever potassium or any of its oxyds come in contact with water. When produced from potassium or the suboxyd just described, an evolution of hydrogen attends the alkalization of the metal, owing doubtless to the decomposition of water: when produced by moistening the peroxyd, the generation of the alkali is attended with the evolution of that portion of oxygen which constitutes the difference between the alkali and the peroxyd, but in either case the contact of water and of potassium in any form determines the formation of the alkali. In this way of forming the alkali it always unites with that portion of water of [illegible] (amounting to about 18 per cent.) [illegible] been mentioned in the beginning of this article, is inseparable from caustic potash prepared by watery solution, even when it has been dried by fusion in a full red heat, and constitutes not properly pure potash, but hydrat of potash. The pure potash can only be obtained by heating the yellow peroxyd to be now described.

The orange-yellow peroxyd of potassium is prepared immediately by igniting potassium in oxygen, or even in common air. The discoveryof the real nature of this oxyd, and of its containing more oxygen than the alkali does, is due to the eminent French chemists already mentioned. There is however some difficulty in performing the combustion accurately. If the potassium is burned upon glass or platina, these are both attacked by the oxyd assisted by the great heat generated, and incorrect results follow. A support of silver answers better, though with some risk of its fusion, or as Sir H. Davy recommends, the potassium may be laid in a small dish of platina, coated over with melted muriat of potash, which is not acted on by potassium or any of its oxyds. The French chemists observe that much of the inconvenience of a platina support may be avoided by using potassium that has been in oil, as it then burns at a lower temperature, or still better by employing the suboxyd which inflames spontaneously in oxygen. They give the results of eight different experiments on the combustion of the same quantity of potassium in a glass vessel full of dry oxygen confined over mercury, the potassium being laid in some experiments on glass, in others on platina, in others on silver. The yellow oxyd thence produced was then thrown into water, by which it passed to the state of alkali, giving out all its excess of oxygen. There is so little agreement in these experiments as to the entire quantity of oxygen absorbed by the potassium, that the composition of the peroxyd cannot be deduced from them. The largest quantity of oxygen absorbed (which is obviously nearest the true estimation) was pretty exactly twice as much as that portion required to convert the given weight of potassium into potash, and the experiments were so far satisfactory, that after the yellow oxyd was plunged into water and had parted with its excess of oxygen, the remainder which entered into the constitution of the alkali was nearly the same in each experiment. This peroxyd is fusible at a lower heat than hydrat of potash, and crystallizes in laminæ by cooling. The colour is yellow when pure but brownish when mixed with oxyd of

[c] Davy.

platina. When thrown into water it gives out pure oxygen gas, and passes to the state of potash as before mentioned. When it is heated very strongly upon a platina support protected by muriat of potash, oxygen gas is given out,[c] and there remains a grey difficulty-fusible substance, vitreous in its fracture which disssolves in water with much heat but without any effervescence, and renders the water alkaline. This grey vitreous substance is considered by Sir H. Davy as pure potash, free from water or any foreign body, and it is the only known method of obtaining quite pure uncombined potash.

This yellow oxyd has a very striking action on all combustible bodies, to all of which it affords its excess of oxygen: in doing so it returns to the state of potash, and the alkali thus generated often unites with some or other of the products. Some particulars of these experiments we shall mention.[d]

Phosphorus heated with the peroxyd in an atmosphere of azotic gas produced a very vivid combustion, so as to redden the whole of the platina capsule in which it was contained. The azote was unchanged. Part of the phosphorus was burnt and part only volatilized. The product did not effervesce with water and with difficulty dissolved in it, though the salts of lime and barytes gave considerable precipitates. The product of this combustion was probably subphosphat of potash.

Sulphur heated in like manner with the peroxyd gave a compound which no longer effervesced with water (and therefore contained no uncombined oxygen) and smelt of liver of sulphur, and at the same time gave a copious precipitate with nitrat of barytes, and hence contained a mixture of a little sulphuret of potash with much sulphat.

Charcoal and the peroxyd heated together gave carbonat of potash.

The following metals, namely, tin, arsenic, antimony, zinc, copper, bismuth, lead and iron, all in fine filings, were separately heated with the peroxyd. In all the peroxyd was reduced to the state of potash but with some variation in the attending circumstances. With the tin, antimony, and arsenic, there was a great disengagement of heat and light, particularly with the former, so that both the capsule of platina on which the materials were placed and the glass vessel that confined them were made red-hot. The zinc and copper were but feebly ignited, and the bismuth, lead and iron not at all. The heat was applied in all these cases with a spirit lamp on the outside of the glass vessel. By putting the product in water all the metallic oxyds were obtained except those soluble in the alkali generated in the experiment.

The peroxyd and potassium heated together in the same way produced potash with much disengagement of light and heat.

The peroxyd was introduced into an atmosphere of hydrogen confined by mercury. No effect was produced at a common temperature, but on heating it a rapid absorption of gas took place with abundance of moisture which streamed down the sides of the vessel, the peroxyd whitened and gradually became changed into potash. No light was disengaged.

Phosphuretted and sulphuretted hydrogen heated with the peroxyd produced in like manner water and potash, and sulphuret and phosphuret of potash.

With ammoniacal gas and the peroxyd the products were water and azotic gas.

The peroxyd was heated with muriatic acid gas. Much of the gas was absorbed, drops of water trickled down the sides of the vessel, oxygen gas was given out, and yellowish white muriat of potash was formed, but no oxymuriatic acid, nor was any light produced.

With carbonic acid gas the peroxyd when heated gave out oxygen gas, and carbonat of potash was produced which strongly effervesced with acids, but no water was generated.

The peroxyd was heated with sulphureous acid gas and the experiment was conducted with much care. The gas was carefully dried and had the specific gravity of 2.2553 (common air being 1.) the quantity of it as well as that of the peroxyd of potassium was weighed, as also was each of the products after the experiments. As soon as the heat was applied a brisk inflammation took place and an abundant absorption of gas. Sulphat of potash was formed, and a little oxygen gas, but not a trace of aqueous vapour. The oxygen was then separated from the undecomposed sulphureous acid, and the weights of the two gasses, added to that of the sulphat of potash, were found to equal that of the sulphureous acid gas and of the peroxyd of potassium employed.

The peroxyd was heated in nitrous gas, but without any particular estimation of quantities. Much absorption took place, very red nitrous acid gas appeared, and a salt was melted to the

[c] Davy. [d] Gay Lussac, and Thenard.

bottom of the retort which was nitrite of potash. Nitrous oxyd produced no alteration whatever on the peroxyd of potassium.

The peroxyd may be made by heating potassium either in oxygen or in nitrous gas or in nitrous oxyd. In the latter cases, the potassium becomes highly oxydated at first, but on continuing the heat, seems to return to the state of alkali, and nitrite of potash is formed.

The French chemists, whose experiments we are now describing, consider the peroxyd of potassium as containing three times as much oxygen as the quantity necessary to convert potassium into potash; so that if potash consists of 84. parts by weight of potassium to 16 of oxygen, the peroxyd of potassium will consist of 84 of potassium to 48 of oxygen, or 63.64 per cent. of potassium and 36.36 of oxygen.

Potassium and Hydrogen. These combine neither at a common temperature nor at a red-heat, but readily at an intermediate degree, such as is produced by a spirit-lamp. Potassium thus heated in hydrogen gas absorbs it rapidly, but gives it out again with equal ease when the proper degree of heat is exceeded. The actual quantity of hydrogen absorbed seems to vary considerably, but on an average it appears to be about a fourth of the quantity which would be produced by immersing the potassium in water. This Hydruret of Potassium is grey, unmetallic in appearance and infusible. It inflames in common air or in oxygen only when heated. It is entirely decomposed into hydrogen and potassium when heated *per se* in a close vessel, and when in contact with hot mercury it is still more rapidly destroyed, the hydrogen flying off and the potassium amalgamating with the mercury.

Phosphorus unites readily with potassium. This compound is made by introducing the two into a glass tube filled with azotic gas and gently warming them. But little light is given out. The phosphuret of potassium has an unmetallic appearance, is of a chocolate colour, and when thrown into water produces phosphuretted hydrogen gas, which sometimes but not always inflames.

Sulphur forms a very intimate union with potassium, and the combination takes place with much more heat and light than in the phosphuret, so as to endanger the glass vessel, unless the sulphur and potassium are placed upon a platina dish within the tube, which last should be filled with azote. This sulphuret is sometimes yellow, sometimes red. It has the smell and taste of rotten eggs, is soluble in water without the production of any gas, but with acids it is readily decomposed with evolution of sulphuretted hydrogen gas.

When potassium is melted in sulphuretted or phosphuretted hydrogen gas, a sulphuret or phosphuret of potassium is formed, and the hydrogen remains pure.

Alloys of Potassium and the Metals.

Potassium very readily unites with many of the metals, as was first ascertained by Davy, and indeed this circumstance is one that is brought forward as an argument of the metallic nature of this singular substance. Some of these alloys, as described by the discoverer, we have already mentioned; the following experiments are given by M. M. Gay Lussac and Thenard. The alloys were made either by heating the substances in a small bent glass tube over mercury and filled with azotic gas, or by introducing the potassium into a small glass tube closed at one end, covering it with the metal in powder, then drawing out the other end of the tube over a lamp and sealing it hermetically, and finally uniting the metal and potassium by a due heat over lighted charcoal.

Potassium 2 measures, lead in powder 8 measures, gave a solid brittle fusible fine-grained alloy. Exposed to air it decomposed gradually, and in water, suddenly. In either case potash was produced and the lead resumed its metallic state. Potassium 2 measures, bismuth 8 measures, a solid brittle alloy in small facets: decomposed as the last. Potassium 2 measures, antimony 8 measures: this mixture alloyed with great ease, giving out light in the process: decomposed as above.

Potassium 2 measures, tin 7 measures. Some light is given out during the union, which requires almost red heat to be effected. This alloy must be made in azotic gas as it is immediately decomposed in the air. When the tin is in a less proportion than the above, the alloy generally takes fire the moment it is attempted to be pulverized.

Potassium and zinc alloy with difficulty on account of the volatility of the potassium at the heat required.

Potassium and mercury will unite in any proportions. When the former was to the latter as 212 by weight to 3069, the amalgam remained fluid at a mean temperature. With twice the above quantity of potassium much heat was excited on mixture, and the amalgam was solid at a common temperature and easily

crystallized. The crystallized texture was still more decided with three portions of potassium. These amalgams will take place without heat when the potassium is free from oil or oxyd on its surface and quite clean. They often occur accidentally by the fall of particles of potassium on the mercury bath, which, as soon as they touch the mercury, move about on its surface with great rapidity, and soon disappear by being absorbed by the fluid metal. Much heat is given out when potassium and mercury unite.

Potassium 2 measures, arsenic 6 measures. This alloy is easily made and much light is given out at the time, but instead of having a metallic lustre it is of a dull chesnut brown hue, and when in contact with water it gives out a much smaller bulk of hydrogen gas than the same quantity of potassium gives when alloyed with any other metal. This gas was therefore examined with more care. A bent glass tube was filled with azote over mercury and 2 measures of potassium, and a piece of arsenic were introduced into the tube and united by fusion. The azotic gas was not in any degree altered. Water was then thrown up which caused a brisk effervescence, and the production of potash, and the alloy was entirely destroyed, leaving only a light flocculent matter like kermes. The water was boiled to compleat the decomposition of the arsenical alloy. The only gas produced was 82 measures of arsenicated hydrogen. This experiment was repeated many times with different proportions of potassium, the gas being always measured, and it was found to be pretty accurately in direct proportion to the quantity of potassium used: but it was also found that the same quantity of potassium which when unalloyed with arsenic gave 79 parts of pure hydrogen, would give only on the average 33.36 parts of arsenicated hydrogen. This led to the analysis of arsenicated hydrogen. This gas was prepared both by moistening the alloy of arsenic and potassium, and by adding muriatic acid to an alloy of 3 parts of tin and 1 of arsenic. A given quantity of this gas was confined in a glass vessel over mercury, in contact with a vessel containing tin which was kept in fusion for three quarters of an hour. This process extracted all the arsenic from the gas, which then returned to the state of simple hydrogen, as was determined by there being not the least deposition of arsenic on the sides of the vessel in which the gas was subsequently burned. From the result of several experiments which agreed sufficiently well, it was shewn that 100 measures of arsenicated hydrogen expand to 140 parts after the extraction of the arsenic. But this circumstance would only account for part of the apparent deficiency in the quantity of gas produced by the action of water on the alloy of arsenic and potassium, for if 140 measures of pure hydrogen produce 100 measures of arsenicated hydrogen, 79 of hydrogen (the quantity produced by each measure of pure potassium) should give 56.4 of the arsenicated gas, whereas the quantity of the latter gas actually produced, was only 33.36. This therefore would imply some loss of hydrogen, or rather a condensation of it in some one or other of the products so as to prevent it from assuming a gasseous form, and this the authors with great probability suppose to be the case in the brown arsenical flocculi that remain after the action of water upon the arsenical alloy, which flocculent matter therefore will then be a *Hydruret of Arsenic.* The possibility of a solid compound of hydrogen and arsenic has also been inferred by Sir H. Davy, as a result of the following experiments on the action of tellurium and arsenic on potassium.[d] Arsenic being made the negative surface in a powerful galvanic action taken in water, became dark coloured and threw down a brown powder, at the same time giving off much inflammable gas. Also an alloy of arsenic and potassium being heated in ammonia produced a gas which was principally azote, and hence the hydrogen of the decomposed ammonia must have entered into combination with the arseniuret of potassium.

Potassium heated in arsenicated hydrogen (to return to M. M. Gay Lussac and Thenard) becomes immediately covered with a red crust, dense fumes condense on the sides of the vessel, the gas is suddenly decomposed, and therefore expanded, pure hydrogen appears, and the arsenic combines with the potassium into a solid arseniuret similar to that produced by the direct union of arsenic and potassium.

Potassium may be readily alloyed with iron by putting some iron turnings in the lower extremity of the gun-barrel that projects beyond the furnace (in the apparatus for obtaining potassium) instead of leaving it empty to receive the condensed potassium. In this case the iron, being long in contact with potassium in vapour, absorbs it, becomes flexible, and often quite soft, and is decomposable in air or water like any of the other alloys of this substance. With-

[d] Phil. Trans. for 1810, p. 27, &c.

out doubt the alloys of the other metals that require a high heat for their fusion might be obtained in this way.

Potassium and Gasseous Oxyd of Carbon have no mutual action at a common temperature, but when heated they readily decompose each other. About 200 measures of carbonic oxyd (obtained from iron filings and carbonat of barytes previously ignited strongly) were heated with a portion of potassium. On the first impression of heat the potassium became blue, but presently took fire, a great and immediate absorption of gas took place, carbon was precipitated, almost all the potassium was changed to potash and the whole gas disappeared except about twelve measures, which were afterwards decomposed in a similar manner by a fresh portion of potassium.

Potassium and Metallic Oxyds. It has been already mentioned that the celebrated discoverer of the alkaline bases ascertained the extreme affinity of potassium for oxygen in every combination, which therefore renders it a most valuable re-agent for an infinite variety of chemical purposes. Among these he discovered that many and probably all the metallic oxyds when heated with potassium, are reduced to the metallic state by yielding their oxygen to the potassium; and if the latter is in excess, the newly reduced metals will alloy with this excess, or will unite with the potash newly formed in case the metals are soluble in this alkali.

Similar experiments have been repeated by the above French chemists on a great variety of metals, and with the same general results. They were all performed in a small glass tube, one end open, the other closed. A layer of the metallic oxyd was first put in, and over it the potassium, well cleaned from oil by blotting paper, and upon this another layer of the oxyd. The tube was then heated over a fire as required. In almost all the cases the reduction of the oxyd was attended with light, and generally the potassium passed to the state of potash, and not to that of either of its other oxyds.

The particulars of these experiments need not be specified in this place.

Potassium and the Mineral Acids. Carbonic acid gas and potassium do not act upon each other at a common temperature, but at a heat approaching a cherry-red, the decomposition is rapid and compleat. The approach to this is shewn by the potassium becoming blue. It then takes fire, and the gas is absorbed almost entirely, leaving a little residue of carbonic oxyd, and an abundance of carbon precipitates. The potash thus generated is partly carbonated.

Potassium and sulphureous acid act on each other when heated, the gas is almost totally absorbed if the potassium be in sufficient quantity, and the solid residue is sulphuret of potash.

In nitrous acid gas potassium inflames even at an ordinary temperature, and burns with a red flame.

With oxymuriatic acid gas the appearances are nearly similar. The potassium burns with a red flame, and muriat of potash is produced.

When potassium is heated with muriatic acid gas, hydrogen is disengaged, and solid muriat of potash results. The quantity of hydrogen is the same as would be given out by the action of water on the potassium, and it is half that of the muriatic acid absorbed.

Vitreous phosphoric acid heated with potassium produces a pretty strong combustion, and red phosphuret of potash is left, which when wetted gives phosphuretted hydrogen not inflammable by exposure to air.

Potassium and Alkaline, Earthy, and Metallic Salts. The action of these substances was ascertained in the same manner as that of potassium on the metallic oxyds.

In all cases the potassium abstracted oxygen from those salts which are known to contain it, and the potassium was generally changed into potash, and not into either of its other oxyds. In many instances light was disengaged at the moment of mutual action. The salts employed were all previously dried as much as possible.

The sulphats heated with potassium were more or less perfectly converted into sulphurets.

The phosphats were in like manner changed to phosphurets, giving when moistened that species of phosphuretted hydrogen which is not spontaneously inflammable.

The carbonats with potassium were decomposed into carbonic oxyd, the base of the carbonat employed, and potash from the potassium.

Muriat of barytes and muriat of soda were not altered by potassium, which sublimed through them, being itself unchanged.

The fluats of soda and lime were equally unaltered.

Borax was unaltered by potassium.

SODIUM.

This substance was discovered by Sir H. Davy a few days after the discovery of potas-

sium, and by the same means, that is, by the electro-chemical action of a powerful galvanic battery acting on solid caustic hydrat of soda. The mode of preparing sodium therefore is precisely the same as that of potassium, substituting one alkali for the other. Sodium may also be readily prepared by igniting common salt and then heating it to redness with potassium in a close vessel. The salt is immediately decomposed, and the sodium rises very pure. No hydrogen is disengaged in this process, and two parts of potassium produce rather more than one of sodium.[a]

Sodium is also prepared by the process discovered by Messrs. Gay Lussac and Thenard, for obtaining potassium, the apparatus being precisely similar, and no other difference being required than to substitute soda for potash as the alkali to be passed through the ignited iron turnings. As solid hydrat of soda contains much more water of composition than hydrat of potash, it should be kept for some time in fusion at a low red heat just before it is put into the gun barrel apparatus. In the distillation, a still greater heat is required to obtain sodium than potassium, and the transmission of the soda through the heated barrel should be slower.

Pure sodium is an opake substance with a white silvery lustre. It melts at about 200° Fahr. if unalloyed with potassium, and it rises in vapour at a strong red heat. It is exceedingly malleable and soft like wax so as readily to be pressed out into thin leaves. Portions of sodium may easily be united into one mass by strong pressure, a species of *cold welding*. Sodium is a very powerful conductor of electricity. Small globules of it inflame by the Voltaic spark, and burn with bright explosions. The specific gravity is given by Davy at 0.9348 (water being 1.0) and by the French chemists at 0.97223.

Before we describe the chemical properties of sodium we shall notice its alloy with potassium, as this very materially alters its fusibility and specific gravity. These two substances unite perfectly, and indeed the alloy is always produced whenever the soda employed for the production of sodium is mixed with any portion of potash. This is the case with all the common soda or carbonat of soda that is used when prepared from barilla, unless particular pains be taken to purify it by repeated solution and crystallization; so that where sodium is to be obtained directly from the decomposition of soda, the alkali manufactured from common salt is perhaps the surest.

When the soda contains as little as five or six per cent. of potash the mixed alkaline metal thence obtained becomes fluid at a temperature little above that at which pure potassium melts, and when the alloy contains more potassium it remains fluid at a common temperature. Three parts of sodium and one of potassium from an alloy fluid at 30°, and which crystallizes into a bright brittle mass when surrounded by salt and ice. Even a thirtieth part of potassium in the alloy materially encreases its fusibility.

An alloy of 10. parts of potassium and 1. of sodium is also fluid at 32°, and is lighter than rectified naphtha. These alloys therefore are in all cases more fusible than pure sodium, and often more so than pure potassium, and they are also always brittle and crystallizable. The alloys may be made either by heating the alkaline metals under naphtha, or even by simple pressure without heat. It should be observed that these alloys are gradually oxydated even under naphtha when exposed for some time to the air, and that it is the potassium which first undergoes this change, and by this means sodium may be purified from a small admixture of potassium, the latter being entirely oxydated before the former is altered.

When sodium is exposed to the atmosphere it immediately tarnishes and gradually becomes covered with a crust of soda which deliquesces. Sodium confined in oxygen gas combines with it slowly and without any luminous appearance at a common temperature, but when heated it burns with a very white brilliant sparkling flame. In common air the flame is yellow.

When sodium is thrown on water it produces a violent effervescence of hydrogen with a hissing noise, the globules run about in all directions on the surface of the water, rapidly lessen without flame or explosion, and gradually disappear, leaving the water alkaline by the soda produced. The quantity of hydrogen produced by a given weight of sodium in water is thus given by Messrs. Gay Lussac and Thenard, whose experiments very closely coincide with the results adopted by Sir H. Davy. The mode of conducting the experiment was exactly the same as with potassium. 2.486 grammes of sodium decomposed by water gave 1.2525 litres of hydrogen gas at 15° centigrade Th. and 0.759 metre Bar.; whence it follows that 100. parts

[a] Davy.

by weight of sodium absorb 33.995 parts of oxygen during its conversion into soda, and therefore 100 parts of pure soda free from all water of composition, contain 74.63 of sodium and 25.37 of oxygen.

The numbers adopted by Davy[b] are 88 of sodium to 30 of oxygen (88 being the number representing one proportion of sodium) which would give 74.5 per cent. of sodium and 25.5 of oxygen.

Oxyds of Sodium. The oxydation of sodium seems in every respect to run a parallel course with that of potassium.

There are three oxyds of sodium known, of which the alkali soda is in the intermediate degree of oxydation.

The suboxyd of sodium is formed like that of potassium by very slow circulation of air in a vessel confined by a cork. This suboxyd is grey, brittle, unmetallic in appearance, and gives out some hydrogen when moistened, but less than sodium.

The pure alkali Soda, free from water of composition forms the next oxyd of sodium. Its composition has just been mentioned. It is formed, like the pure potash, by heating the peroxyd. When produced by the action of water on sodium it always retains a considerable portion of water which is not expelled even at a red heat.

The peroxyd of sodium is formed as the peroxyd of potassium by heating the alkaline basis in oxygen gas. Its natural colour is a dirty yellow; but brown when prepared upon uncovered platina. When thrown into water it is immediately decomposed and passes to the state of alkali, giving out oxygen gas.

The experiments made by the French chemists to find the utmost quantity of oxygen gas absorbed by the combustion of sodium, in no degree accord with each other, except to shew that the term of oxygenation that produces the alkali is pretty accurately defined.

But beyond this, the excess of oxygen absorbed to produce the peroxyd (and which excess is given out when water is added) varies so much in the experiments given that no accurate inference can be made. The utmost quantity of this excess is somewhat more than half the quantity of oxygen absorbed to produce the alkali, and this proportion is also given by Sir H. Davy. Hence it may perhaps be allowed that sodium with two portions of oxygen becomes soda, and with three portions the peroxyd,[c] We may add that a very considerable error has crept into the calculations of these eminent chemists from their own data. The quantity of oxygen absorbed by one measure of sodium is *not* 148 of the measures used, but half this number, or 74. It is the hydrogen given out which is 148, and hence the oxygen absorbed would be half this quantity *in bulk*, or 74; and this too agrees with the other numbers of the table given, being pretty nearly the quantity left after the action of water on the peroxyd in all the five experiments.

The chemical properties of sodium, and its oxyds so closely resemble those of potassium in parallel cases as to render a particular description unnecessary. In almost every instance sodium absorbs oxygen from every substance containing it (the oxyds of potassium excepted) and the peroxyd yields that excess of oxygen above the quantity necessary for alkalization to almost every substance which has an affinity for oxygen.

Oxygenation of the common caustic alkalies by fusion. After the discovery of the peroxyds of potassium and sodium it was natural to examine whether any process of superoxygenation of the alkalies in their common state (that is as *Hydrats*) ever took place, when they were kept in fusion at a red heat exposed to the atmosphere. At a common temperature it is obvious that the deliquescence of these alkalies would of itself prevent any higher degree of oxygenation; and as even at a red heat the water of composition entering into these alkalies is not driven off, it was doubtful whether this circumstance might not oppose the further absorption of oxygen. Messrs. Gay Lussac and Thenard however assert that when common caustic potash or soda, prepared by alcohol, is kept in fusion at a red heat in an open crucible of silver platina or earth, it absorbs oxygen and partly passes to the state of peroxyd, and will again give out oxygen gas on being dissolved in water. A silver crucible answers best as the alkali has no action on it. Potash oxygenates sooner under these circumstances than soda, so that in eight or ten minutes of fusion its colour deepens and it gives out much oxygen when wetted. But when the alkali is combined with carbonic acid no such superoxygenation takes place by any length of fusion.

On the other hand they assert that the nitrats of these alkalies when thrown into a red hot crucible and kept long enough to be completely decomposed, very readily furnish the peroxyds of the alkaline bases.

[b] Elements. [c] See Recherches, &c. par MM. Gay Lussac and Thenard, tom. i. p. 513.

ALLANITE.[a]

This mineral occurs in oblique tetrahedral prisms, the alternate angles of which measure 117° and 63, or in compressed hexahedral prisms terminated by tetrahedral summits; it also occurs uncrystallized and then is either massive or disseminated being mixed with black mica and felspar. Its specific gravity as far as can be ascertained on account of the intimately intermixed mica, is between 3.1 and 4.0. Its colour is brownish-black; when bruised dark greenish grey. Externally it is dull. Internally it exhibits a small conchoidal fracture with a shining lustre between resinous and metallic. It is opake, in hardness ranks between felspar and glass; is brittle and easily frangible. Before the blow-pipe it froths and melts into a brown slag. It gelatinizes in nitric acid, and loses about 4 per cent. of its weight by strong ignition.

The substances obtained from 100 parts of it on analysis by Dr. Thomson, are

35.4	silex
9.2	lime
4.1	alumine
25.4	per-oxide of iron
33.9	oxide of cerium
4.0	volatile matter
112.0	

Allanite is a native of Greenland, but of its geological history we are as yet entirely ignorant.

ALLOCHROITE.[b] Splittriger Granat K.

The colour of this mineral is yellowish or brownish-grey. It occurs in opake amorphous masses. Its fracture is uneven passing to splintery, with a slight degree of lustre. It gives sparks with steel, and is difficultly frangible. Sp. gr. 3.5. Before the blow-pipe it is fusible without addition into a black shining opake enamel.

It has been analysed both by Vauquelin and Rose, with the following results:

V.		R.	
35.	—	37.	silex
30.5	—	30.	lime
8.	—	5.	alumine
17.	—	18.5	oxide of iron
3.5	—	6.25	oxide of manganese
6.	—	0.	carbonate of lime
100.0		96.75	

This mineral is considered by Karsten as a variety of garnet, and in fact its analysis nearly coincides with that of melanite or black garnet.

It occurs generally in pieces covered by carbonate of lime, and by dodecahedral crystals which appear to be garnet. These dodecahedrons are implanted by their lower extremities in the allochroite, into the substance of which they appear to pass by insensible degrees. The carbonate of lime in Vauquelin's analysis is no doubt foreign to the composition of this mineral and is to be attributed to the calcareous spar with which it is mixed.

It occurs in the iron mine of Virums, near Drammen in Norway.

ALOE.

Three analyses have been made of this substance, of which the following is an abstract. The first we shall mention is that of M. Braconnot.[c]

Aloes is a dark brown semi-transparent extract, easily reduced to powder, and very bitter, prepared from the natural juice of several species of the aloe plant, either by natural or artificial heat. The finest species is prepared only by inspissation in the sun's heat. The finest sort was selected for the following experiments:

50 grammes were heated *per se* in a retort, with a heat at first very gentle, and afterwards increased. The first product was a water loaded with the flavour of aloes, then a colourless water holding some acetous acid but no ammonia: then a red oil soluble in alcohol; and then at a higher heat much carburetted hydrogen with oil. The coal contained no potash.

Aloes rubbed in a mortar with water produces a viscous mass like turpentine when pressed with the fingers. A large quantity of water however dissolves the whole, excepting a little woody impurity, and the solution of the last portion is as bitter as the first. By heating the water, the solubility of aloes is greatly increased, and the hot saturated solution will assume somewhat of a crystalline form by cooling. The watery solution of aloes reddens litmus. Its colour is rendered deeper by lime-water and the alkalies, but nothing is precipitated. Goulard's extract produces a deep precipitate, and the supernatant liquor becomes colourless.

The watery solution when long exposed to the air becomes mouldy, and then gives an abundant precipitate with gall-nut, but when

[a] Nich. Journ. xxix. 48. [b] Hauy Tab. Comp. 57. [c] An. Chim. Tom. 68.

the solution is recent this reagent only slightly disturbs it.

Spirit of wine dissolves aloes with great ease when warm. The solution is of a very deep red, and water added to it gives a copious pale yellow sediment. If the spirituous solution is much lessened by evaporation, the slightest agitation causes the surface to assume a crystalline form.

Neither the fixed nor the essential oils dissolve any sensible portion of aloes.

All the alkalies dissolve aloes very easily even without heat, and the intense bitter is somewhat corrected in this solution.

The ammoniacal solution carefully evaporated almost to dryness, gave the author a number of needled crystals impacted in a resiniform mass. These crystals gave the smell of ammonia when rubbed with lime and moistened, and hence this alkali appears to be one of their component parts.

Weak acids merely dissolve aloes, and somewhat more abundantly than water does.

Nitric acid dissolves it easily in the cold, producing a blood-red liquid, precipitable by water. A quantity of aloes was put into a retort, and heated cautiously with eight parts of strong nitric acid. Abundance of nitrous gas was given out, and when this action had ceased the retort contained a yellow liquid, which on cooling deposited a good deal of a yellow flocculent substance, that weighed after washing on the filter about a quarter of the weight of the aloes employed. The author considers this as an acid possessing some peculiar properties, and terms it the *Aloetic Acid*. It is of a very fine yellow and intensely bitter, not crystallizable, reddens litmus, and effervesces with the alkaline carbonates. Its smell is agreeably aromatic when warmed. It is very slightly soluble in water, and the solution has the colour of arterial blood. Alcohol dissolves only $\frac{1}{30}$ of its weight of this acid. The mineral acids merely dissolve without decomposing it. Potash forms a red crystallizable salt with this acid, which detonates with the violence of gunpowder when heated sufficiently or touched with an ignited body. The salt is easily produced by pouring a weak solution of caustic potash on the yellow aloetic acid.

The liquor that remains after the extraction of this acid from the heated mixture of aloes and nitric acid, contains also much oxalic acid, so as to give a copious precipitate of oxalate of lime on the addition of nitrat of lime.

M. Braconnot infers from his experiments, that the chief constituent part of aloes is neither a gum nor resin, but a substance *sui generis*, which he terms *Bitter Resin (Resina Amar.)*

M. Trommsdorff has given a comparative analysis of the Socotrine and Hepatic aloes,[d] of which a few particulars may be mentioned. Four ounces of aloes were boiled with 3 pints of distilled water. The whole dissolved, but became very turbid on cooling, and a yellow substance separated, weighing an ounce after drying. This substance was a bitter, yellow, brittle, transparent resin, fusible at a gentle heat, insoluble in water, very soluble in alcohol and potash, and highly inflammable.

The liquor that contained that part of the aloes which remained soluble in water, was evaporated to dryness, and gave a brown bitter mass equally soluble in water and alcohol, but insoluble in ether, which the author considers as identical with what Hermbstaedt terms the *Saponaceous Principle* of vegetables. Another portion of aloes was analyzed by first digesting it in alcohol, in which it totally dissolved without any residue but a few grains of woody impurity. The solution remained clear after cooling. After being evaporated to dryness, the residue was digested with water, and only three fourths of it dissolved, leaving one fourth of resin; which confirmed the general proportion of resin and other matter found in the first experiment.

Some difference was found in the subsequent analysis of the *Hepatic* aloes, this species containing about $\frac{1}{8}$th of albumen which resisted solution in boiling water and in alcohol, owing to its coagulation. This therefore is given as a mode of distinguishing the two species; the Socotrine aloes dissolves entirely in boiling water and in alcohol, but the Hepatic when thus treated, leaves a portion of coagulated albumen.

Further experiments have been made upon aloes by Messrs. B. La Grange and Vogel,[e] with some slight difference as to results.

A portion of each kind of aloes was distilled *per se*. Some water and oil passed over, the former of which gave a brownish-black colour to sulphate of iron, but this tinge did not resemble that produced by the distilled water of the gall nut; neither was the water of the aloes at all altered in colour by lime, barytic or strontian-water, all of which give a blue, green, or rose-colour precipitate with these

d An. Ch. tom. 68.

e An. Ch. tom. 68.

reagents. Hence the authors conclude that aloes contains no gallic acid. The distilled water of the hepatic aloes gave a sensible quantity of ammonia.

A second distillation of each species of aloes was made with the addition of water in the retort. The socotrine aloes gave a pleasant sweet-smelling water, not acid, on which floated a greenish yellow oil smelling like melilot. The distilled water of the hepatic aloes on the other hand was nauseous, and no oil separated.

The action of cold water on aloes was somewhat different from that observed by M. Braconnot. The latter chemist asserts that cold water in sufficient quantity will dissolve the whole of the aloes, and that the last dissolved portion equals the first in bitterness. On the other hand, the authors of the present paper found that by digesting the aloes with successive portions of cold water, and pouring off the liquors after remaining for some hours in contact till nothing more was extracted, there remained a soft grey elastic mass insoluble in water, resembling a resin. The watery solution is thick and lathers much on agitation. It deposits a yellow powder on the addition of a great variety of substances, such as all the mineral acids, all the neutral, and a great many of the metallic salts. Those of iron produce a brown precipitate, but different from that given by galls. All these precipitates from the aloetic solution are soluble in water. The watery solution, evaporated slowly to dryness, leaves a brown transparent vitriform mass intensely bitter, and perfectly soluble in water and alcohol, but very sparingly in ether.

On the other hand the resinous matter of aloes is not soluble in cold water, but dissolves in alcohol and ether, and the latter solution is abundantly precipitated by water.

The action of nitric acid observed by these chemists was nearly the same as that described by M. Braconnot. The yellow powder produced by heating aloes in this acid, gives a most beautiful purple colour to a large quantity of water. When this powder is gently heated *per se* in a retort, as soon as it melts, it explodes slightly, and an acid yellow bitter liquor passes into the receiver, smelling of prussic acid and evolving ammonia on the addition of potash.[a]

Oxymuriatic acid passed through a concentrated watery solution of aloes is absorbed in great quantity, the liquor becomes yellow and coagulates strongly so as almost entirely to solidify. This coagulum when washed is elastic, insoluble in cold water, but abundantly soluble in alcohol, which solution is copiously precipitated by water. The action of oxymuriatic acid therefore appears to convert much of the aloes into a perfect resin.

ALUM.

§ 1. *Ores and Manufacture of.*

The largest alum mine in Britain is at Hurlett near Glasgow.[a] In the colliery at that place is a bed of coal about five feet thick covered by a roof of pyritical slaty clay of the thickness of ten inches. The coal with the superincumbent roof dips just enough to afford a free passage for the water, and the mine is worked, contrary to the usual practice, from the rise to the dip; hence all the workings are necessarily kept perfectly dry. For three centuries has this colliery been in work, and it now presents an excavation the area of which is nearly a mile square, with pillars of coal at the usual intervals in order to support the overlying beds, the thickness of which is on an average about 30 fathoms. The air circulates slowly through the whole of this space by means of such of the old shafts as still remain open; and, in consequence, a slow decomposition of the roof is perpetually going on. This process however is so gradual that in no part has the slate been hitherto entirely removed.

The first action of the air is to cause a thin flake to scale off from the roof and fall upon the dry floor; in this last situation the decomposition makes further progress, and by degrees assumes the appearance of a light spicular efflorence. Succeeding flakes go through a similar process, and in time the whole space up to the very roof itself is completely filled; the current of air being then obstructed, all further decomposition of course ceases till the effloresced portion is removed.

The mass thus obtained consists of earth richly impregnated with sulphate of alumine, sulphate of iron, and in some cases with sulphate of magnesia. The salts are separated by lixiviation from the insoluble residue, the sulphate of alumine is converted into alum by the addition of sulphate or muriate of potash, and the manufacture is finished in the usual way.

The oldest alum works in this country are at Whitby in Yorkshire,[b] where there occurs a vast deposit of alum slate about twenty-nine miles broad from N. to S. and stretching from the eastern coast even into Lancashire. The depth of this mass is unknown, but it is covered

[a] Ph. Journ. xvi. p. 233.

[a] Ph. Journ. xvi. p. 233.

[b] Ph. Journ. xxv. p. 241.

by alluvial soil, by sandstone lying upon or sometimes inclosing a thin bed of coal by ironstone, shale and clay.

The alum slate itself, although tender near the surface, is at the depth of about 100 feet equal in hardness and compactness to common roof-slate. The upper part, whether from being actually richer in pyrites, or in a state of partial decomposition, is found to yield four or five times as much alum as the lower part, this latter being at the same time considerably more bituminous. Ammonites, nautilites, and trochites, together with belemnites, abound in the schistus; vertebræ and other bones of amphibious animals are also met with. Wood converted by bituminization into a more or less perfect jet is of not unfrequent occurrence, and several subordinate beds of iron ore are worked at the depth of about 200 feet.

The alum slate being procured by means of the pickaxe, the first process to which it is subjected is roasting. For this purpose a bed of faggots and brushwood four or five yards broad and two yards high is covered to the heighth of about four feet with the ore broken very small; it is then kindled, and fresh ore is continually added; the breadth of the pile is also increased by successive additions of faggots and ore till at length the mass reaches the heighth of 80 or 100 feet, covering an area 150 or 200 feet square, and containing about 100,000 cubic yards of ore. The combustion is moderated by covering the surface with the more earthy part of the ore, and after a time it is extinguished spontaneously.

Of this calcined mine it takes on an average 130 tons to produce one ton of alum. For this purpose the ore is steeped in pits containing about 60 cubic yards at a time, and the solution (technically called alum liquor) is drawn off into a cistern, from which it is again pumped upon fresh calcined mine. This process is repeated till the liquor acquires a specific gravity of 1.15. The ore after having been once steeped is lixiviated again a second and third time, and these weaker solutions are used instead of water in subsequent steepings.

The strong liquor is drawn off into cisterns where it deposits much selenite and oxyd of iron; it is then boiled for a short time and allowed to cool, by which nearly the whole of the grosser impurities are got rid of. The liquor thus clarified is transferred to a leaden boiler, where it is mixed with a quantity of mother liquor and kept briskly boiling during the whole day, the loss from evaporation being from time to time supplied by fresh liquor. The concentrated solution from the whole of the pans is run every morning into a vessel called a settler, where its specific gravity is taken, and is generally found to vary between 1.45 and 1.5: a solution of crystallized muriate of potash is then added, sufficient to lower the specific gravity to 1.35, and the whole is carefully mixed together. The liquor then stands in the settler about two hours in order to deposit the sediment which it contains, and when clear is transferred into the coolers to crystallize. After standing four days the mother liquor is drained off, and the crystals of alum washed with water in a tub, whence they are conveyed to a bin with holes in the bottom that the moisture may run off. The washed alum is then put into a large leaden pan with as much water as is requisite to hold the salt in solution at a boiling heat; the solution being complete the hot liquor is immediately run into casks. Here it remains about sixteen days; at the end of which time the casks are taken to pieces in order to get out the hollow mass of alum entire; this latter is then pierced, the mother liquor is let out and the alum itself being cleared from any adhering dirt is broken into pieces of about 1 cwt. each, and is ready for sale.

130 tons of calcined mine afford 1 ton of alum.

The daily produce of each pan is about 4 cwt. of alum, for which about 18 bushels of coal are required.

22 tons of muriate of potash are necessary for every 100 tons of alum.

§ 2. *Analysis of Alum.*

The most accurate analysis of alum is by Vauquelin*; in his comparative examination of several varieties of this salt, for the purpose of ascertaining whether there is any such real superiority of the Roman alum, and of certain other foreign varieties of the same substance, over the French manufactures of this article as it seems, is generally supposed by the French dyers and calico-printers. The four most interesting varieties out of the six which were analysed by this able chemist, were the following: 1. Genuine Roman alum. 2. Ditto from a manufacture at Liege. 3. Ditto English. 4. Ditto French from the manufacture of M. Ribaucourt.

The method pursued was to dissolve the alum in water, and by the addition of ammonia in excess to separate the alumine and oxide of iron, the precipitate being perfectly well

* Ann. Chim. I. p. 154.

washed was dried and finally ignited in a platina crucible. A fresh portion of alum was then taken and decomposed by muriat of barytes for the purpose of ascertaining the amount of sulphuric acid from the sulphate of barytes produced. The ammoniacal liquor in the first process was evaporated to dryness, the residual salt was ignited in order to drive off the sulphate of ammonia, and the remainder was sulphate of potash. A fresh portion was boiled in a retort with caustic potash, and the ammoniacal liquor which came over was saturated with sulphuric acid and then evaporated; the remaining sulphate of ammonia indicated the amount of volatile alkali contained in the alum. Lastly, the alumine obtained in the first process was digested in caustic potash till the whole of the earth was taken up, and thus separated from the oxide of iron which is insoluble in this menstruum. From analyses carried on in the manner just mentioned it appears that the following are the component parts of the four varieties of alum examined by M. Vauquelin, viz.

Roman		Liege		English		French	
10.36	—	10.39	—	10.21	—	10.16	Alumine
31.82	—	31.49	—	31.64	—	31.49	Sulphuric acid
12.17	—	12.17	—	12.20	—	12.45	Potash
0.	—	0.29	—	0.47	—	0.41	Ammonia
0.	—	0.098	—	0.246	—	0.252	Oxyde of Iron
54.35	—	54.438	—	54.766	—	54.772	

What remains to be added to each, that the original 100 parts may be complete, is water of crystallization.

Hence it appears that the sole difference between the most and the least valued kinds of alum is that the latter contains a few thousandths of the sulphates of ammonia and of iron, which are wholly or almost wholly wanting in the former. It became therefore a matter of importance to ascertain by direct experiment the effect of a small portion of these salts upon the more delicate dyes, and in consequence an investigation to this purpose was undertaken by M. M. Thenard and Roard.[a]

The result of their inquiry has been, that in dying *wool* with the most delicate colours, such as weld, cochineal, sumach, madder and kermes, the use of Roman instead of common alum is of little or no consequence; that the colours of *cotton* are sensibly deteriorated by the employment of impure alum, and that this effect is still more sensible in the dying of *silk*. Sulphate of ammonia even in much larger doses than it exists in the most impure alums is very little injurious, it is therefore the sulphate of iron that produces all the mischief.

Having thus ascertained that the preference given to the Roman over every other kind of alum in the market is by no means a prejudice, but founded on very substantial reasons, M. M. Thenard and Roard proceed to show that it is very easy to get rid of the sulphate of iron, and thus to raise the most impure alums compleatly to the standard of the Roman. For this purpose the alum is to be dissolved in as small a quantity as possible of boiling water, and the solution while cooling is to be incessantly stirred; by this means the alum will be obtained nearly in a pulverulent state; it is then to be carefully washed two or three times in small portions of fresh water, and the purification is compleat. [For the experiments of Thenard and Roard on the action of alum on colouring matter, see the article DYING in this Appendix.]

ALUMINUM.

The metallic basis of alumine has not yet been obtained in a free state, though sufficient indications of its existence have been made out by Sir H. Davy.[a] When iron is negatively electrified with a high galvanic power and fused in contact with moistened alumine, a globule is obtained whiter than pure iron, which slowly effervesces in water and becomes gradually covered with white powder; and the solution in muriatic acid decomposed by an alkali gives alumine and oxyd of iron. Also when potassium is vaporized by heat, and in this state passed through alumine heated to whiteness, much potash is formed which produces a coherent mass with the undecomposed alumine, in which are found numerous grey particles which become white when heated in the air, and slowly effervesce in water. These grey particles appear to be an alloy of potassium and aluminum.

AMMONIA. AMMONIUM.

The following practicial remarks on the preparation of the liquid ammonia may be

[a] Ann. Chim. lix. p. 58.

[a] Elements of Chemistry.

useful. Mr. Phillips has the following experiment.[a] To 9 oz. of lime slacked with half a pint of water, and put in a closed vessel, were added 12 oz. of muriat of ammonia, and 3 ½ pints of boiling water. The mixture having cooled, the clear solution was divided into two equal portions and separately distilled, without putting any water in the receiver or employing pressure. Ten ounce measures of distilled liquor of ammonia were obtained from each portion, of the specific gravity of .954, which according to Davy's tables indicates about 11½ per cent. in weight of the pure alkali. The quantity of lime here used is amply sufficient, indeed the same weight as the muriat of ammonia would be sufficient, if the lime is made from marble or any pure limestone, and thoroughly well burnt.

Mr. Dalton[b] has given a table of the strength of ammoniacal solutions somewhat differing from that of Davy. The data which Mr. Dalton assumes, (from particulars which need not be here enlarged upon) and on which the accuracy of the table depends, are the following:

100. water-grain measures of liquid muriatic acid of 1.074 sp. gr. contain 11. grains of real acid: the specific gravities of muriatic acid gas and ammoniacal gas are in the respective proportions of 1.23 and 0.6 and 11. measures of the acid gas saturated 12. measures of the ammoniacal gas. No allowance is required for condensation in constructing the following table, it having been found both by Davy and Mr. Dalton, that when liquid ammonia is mixed with water, the specific gravity is as nearly as possible the mean of the two. Mr. Dalton's table is the following.

Specific gravity.	Grains of ammonia in 100 water-grain measures of liquid.	Grains of ammonia in 100 grains of the liquid.
.85	30.	35.3
.86	28.	32.6
.87	26.	29.9
.88	24.	27.3
.89	22.	24.7
.90	20.	22.2
.91	18.	19.8
.92	16.	17.4
.93	14.	15.1
.94	12.	12.8
.95	10.	10.5
.96	8.	8.3
.97	6.	6.2
.98	4.	4.1
.99	2.	2.0

Analysis of Ammonia.

In the article *Ammonia* (Chem. Dict.) we mentioned the experiments of Priestley, Berthollet, and other chemists, which shewed this alkali to consist of azote and hydrogen, in the proportions of about 4 parts by weight of the former, and 1 part of the latter. A number of important researches have since been made by several eminent chemists, which require a detailed notice.

The fixed alkalies being proved by Davy to be compounds of a peculiar metallic base and oxygen, it naturally occurred to this eminent philosopher that the analogy with the other alkalies would infer a similar composition in the volatile alkali, which however seemed to be contradicted by the experiments of Berthollet and Sir H. Davy himself, in which ammonia was wholly resolved into azote and hydrogen, unless either of these latter substances was itself an oxyd of some unknown base.

A very laborious series of experiments on the analysis of ammonia by electricity and combustion with oxygen and other gasses, has been published by Dr. Henry,[c] which we shall detail somewhat at large, on account of the great importance of the subject, the admirable practical skill and ingenuity with which the experiments were carried on, and the clear idea which it gives of the extreme difficulty which exists in obtaining perfectly accurate results in these delicate operations, from a variety of causes that are here explained.

The first object is the apparatus. Dr. H. found in former experiments that in the usual way of electrizing gasses, a temporary communication is made with the atmosphere at the moment of the explosion, which in the course of a long experiment is sufficient to introduce so much atmospherical air, as sensibly to affect the result. The only unobjectionable way, as Dr. H. mentions, is to inclose and hermetically seal the explosion wires in glass tubes, and then to grind away so much of the glass as will expose the ends of the wires. Those employed in these experiments were of platina, $\frac{1}{50}$ of an inch in diameter.

The next and most difficult object is to free the ammoniacal gas entirely from water. The avidity with which this gas retains moisture is very remarkable. A confined quantity of common air may be so completely desiccated in a few minutes by pure dry potash or dry muriat of lime, that no ice shall appear on the

[a] Examinat. of the Pharm. Lond. 1811. [b] New System of Chemical Philosophy, vol. 2d. [c] Philos. Trans. for 1809.

surface of the vessel when exposed to a cold of $-26°$. But ammonia requires exposure during some hours to potash to stand the test even of the temperature of 0. and a single transfer of the dried gas through mercury in ordinary use, again communicates moisture to it. The gas employed in these experiments was dried by sticks of pure potash fastened to steel wire, so that they could be withdrawn through the confining mercury when their drying action had ceased, and this was ascertained by applying ether or salt and snow to the outside of the glass. In some of the first experiments Dr. H. found that though the gas thus prepared deposited no moisture by cold before electrization, yet it gave a sensible quantity afterwards; but on applying heat just before the experiment both to the mercury and the iron cistern containing it, this condensation of moisture after electrization no longer appeared; at least only in the slightest possible degree; so that it seems necessary for perfect accuracy to heat the mercury and vessels as well as to dry the gas, and even to boil the mercury in the tube before admitting the ammonia.

With these precautions given quantities of ammonia were subjected to long continued electrization, by which (as already mentioned in our former article) the bulk of the gas is nearly doubled, and when no further increase takes place, the residue has now lost its alkaline properties, and is entirely resolvable into azote and hydrogen. Dr. Henry found from the mean of six experiments that 100 measures of pure ammoniacal gas were resolved by electricity into 198.78 measures of the mixed gasses, but the results of the experiment on which he placed the most confidence, on account of the scrupulous precautions observed against the intrusion of moisture, gave an increase of only 180.6 from 109 of ammonia.

The proportion of the hydrogen and azote to each other was ascertained by passing into the mixture a known quantity of oxygen gas, firing it with the electric spark, and estimating the hydrogen thus consumed, the azote being unaltered and constituting the chief part of the residue. In making this estimation, two measures of hydrogen are reckoned as saturating one measure of oxygen for the composition of water. Even this part of the experiment is liable to some inaccuracy as Dr. H. observes, for it is necessary to use a redundance of oxygen gas to explode the whole of the hydrogen, but it is by no means certain that a small portion of the azote will not also undergo combustion into nitric acid which will be absorbed by the water generated. On the whole, Dr. Henry estimates the entire mixed gasses produced by the electrization of the ammonia, to be composed of about 74 measures of hydrogen to 26 of azote.

The extreme labour of decomposing ammonia by mere electricity, led the author to attempt a shorter mode of analysis. Ammonia and atmospherical air will not explode by the electric spark in any proportions, but Dr. H. found that ammonia and oxygen gas when mingled in proper proportions, may be detonated over mercury by the electric spark with as much ease as a mixture of hydrogen and oxygen, and this experiment affords a very ready way of analyzing ammonia with infinitely less labour than by simple electrization, and with as much accuracy, provided proper precautions are observed.

With a greater proportion of pure oxygen gas to ammonia than that of three to one, or of ammonia to oxygen than that of three to 1.4 the mixture ceases to be combustible, but when the proportions best adapted to inflammation are used, the oxygen may be diluted with six times its bulk of common air, without losing its property of burning ammonia.

The products of the combustion of ammonia with oxygen vary essentially, according to the proportion of the gasses used. If the oxygen gas be as much as double the ammonia, the ammonia entirely disappears, as well as the hydrogen, and the only residue is azote with the excess of oxygen. The moment after the detonation, a white cloud settles on the inner surface of the tube, which is too small for analysis but is probably nitrat of ammonia, the nitric acid being formed by the oxygenation of a portion of the azote. Hence when the oxygen of the residue is removed by sulphuret of lime or any other eudiometrical process, the quantity of azote remaining is less than ought to be produced from the ammonia decomposed.

On the other hand when less oxygen is added at first to the ammonia than is sufficient to saturate all the hydrogen, that is to say, when the ammonia much exceeds the oxygen, no nitrat of ammonia appears, the mixture being free from cloudiness, and the mixed gas remaining after the first detonation will completely lose its hydrogen by a second admixture with oxygen and firing, and the azote will remain untouched.

Dr. Henry gives the results of comparative experiments in the two cases, that is, where an excess of oxygen was first employed; and where a deficiency was used. In the first case the oxy-

gen used was twice the measure of the ammonia: the whole was decomposed by a single explosion; and the hydrogen being estimated as equal to twice the bulk of the oxygen that disappeared, and the residuary azote being measured after the removal of the remaining oxygen by sulphuret of lime, the composition of 100 measures of ammonia was estimated to be 84.29 hydrogen, and 15.71 azote, numbers far remote from those given by all the other modes of analysis.

On the other hand, when the ammonia was fired with a deficiency of oxygen gas, 63 measures of the former were exploded with 33 of oxygen holding 1. of azotic impurity. These were diminished to 57 by the first explosion, and no part of the residue was absorbable either by water or by sulphuret of lime, shewing that the whole of the ammonia was decomposed, and that all the oxygen employed had been consumed. The remaining 57. measures (consisting of hydrogen and azote) were detonated with a further addition of 40. of oxygen, and the residue after this second detonation amounted to 60, which was further analyzed by sulphuret of lime. By calculating as above, reckoning 2 measures of hydrogen for every measure of oxygen actually consumed, it appears that the original 63 measures of ammonia furnished by decomposition 31.34 of azote and 88.66 of hydrogen, and hence 100. measures of ammonia would furnish 73.88 of hydrogen to 26.12 of azote.

Dr. Henry gives the results of six experiments on the decomposition of ammonia with a deficient proportion of oxygen, but we must confess that though they attest the care and fidelity of the experimenter, there is not quite sufficient agreement between them to lead us to place implicit confidence in this mode of operating, even in the most skilful and practised hands. The proportion of permanent gasses to the ammonia decomposed, (the azote being actually measured, and the hydrogen estimated by doubling the oxygen expended) varies not inconsiderably in the six experiments, the highest being 198¼, the lowest 180.2 from 100 of ammonia. This shews a correspondent variation of from 66 to 72.2 of oxygen required to saturate all the hydrogen of 100. measures of ammonia, a variation which, however, is probably not more than may be expected in the best conducted experiments on such a complicated subject that requires such a variety of precautions to ensure a tolerable uniformity.

The author ascribes these variations chiefly to the great difficulty of expelling all adhering moisture from every part of the materials and apparatus employed, and his general result is that the proportion of oxygen most precisely necessary to saturate 100. measures of ammonia is 67½, (or 100. of oxygen to 148 of ammonia) and the 100 measures of ammonia will afford about 136 measures of hydrogen and 47 of azote.

Dr. Henry also finds that ammonia will explode with nitrous oxyd and with nitrous gas.

A series of experiments on the decomposition of ammonia has also been published by Mr. A. B. Berthollet,[d] the principal object of them was to examine a position laid down by Davy, (which we shall presently notice) that ammonia contains about $\frac{1}{14}$ of its weight of oxygen. M. A. B. Berthollet relates several experiments relative to the de-oxydation of iron in ammoniacal gas, and the decomposition of ammonia by its passage through an incandescent tube; and by electricity. In the latter method he gives as the mean of six experiments, that 1. measure of ammoniacal gas dilates by electrization into 2.04643 measures of hydrogen and azote.

His general results are that 1 *litre* of ammoniacal gas is decomposed into 2.016 *litres* of mixed gas, of which 1.545 is hydrogen, and 0.146 is azote. The weight of this quantity of hydrogen is 0.146 *grammes*, and that of the azote is 0.630 grammes, amounting in the whole to 0.776; and the weight of a litre of ammonia is 0.775 grammes, which agrees so nearly with the former as to demonstrate (if the data be correct) that ammonia contains no oxygen, nor other constituent part besides hydrogen and azote. It must be observed, however, that the experiments of this ingenious chemist (now no more) do not appear to have been conducted with the same scrupulous attention as those of Dr. Henry. In particular, the means used for depriving the gas of moisture were not so carefully attended to; and in the analysis by combustion with oxygen, an excess of this latter gas was used, which produced so much nitric acid as sensibly to redden litmus, and thus to embarrass the results. The presence of moisture will account for the greater expansion by electrization which this chemist gives; for Dr. Henry uniformly found, when the ammonia was at the driest, that the expansion never quite doubled the original volume of the ammonia.

Mr. Dalton agrees with Sir H. Davy and Dr. Henry, that the volume of ammonia is not doubled by decomposition, but that 100. measures of ammonia give from 185 to 190 of the mixed gasses, the respective proportions of

[d] Mem. d'Arcueil, tom. 2.

which are about 28 measures of azote gas to 72 measures of hydrogen in the hundred.

Mr. Dalton adds the following estimation.

100 measures of ammonia at .6 sp. gr. weigh 60 grains.

These become by decomposition 185. measures of mixed gas,

Namely	51.8 of azote which at	.967 sp. gr. weigh	50.09
	133.2 of hydrogen	.08	10.65
			60.74

Here the united weights of the hydrogen and azote equal and a little exceed the weight of the ammonia, and hence this alkali cannot contain any other constituent part than azote and hydrogen.

Mr. Dalton remarks on the analysis of ammonia by mixture with oxygen and detonation, that notwithstanding the elegance and expedition of Dr. Henry's method, it appears probable that a compound combustible such as ammonia is, can never be totally decomposed and one of its elements burnt, to the entire exclusion of the other. Thus in a mixture of carbonic oxyd and hydrogen, phosphorus, &c. where one of the elements seizes oxygen with more rapidity than the other, it is impracticable totally to oxygenate one of them, and leave the other untouched. With ammonia it is confessedly so where an excess of oxygen is used, (nitric acid appearing along with the water produced) and Mr. Dalton conceives that this is in some degree the case in whatever proportions they are fired. On the whole he prefers employing nitrous oxyd. When 100. measures of ammonia are exploded with 120. of nitrous oxyd, the gasses resulting are azote with only a very small portion of hydrogen. If to this a little hydrogen be added, and then an excess of oxygen, another explosion will determine the residuary hydrogen before explosion, which being deducted, there remain about 172 measures of azote, 120 of which come from the nitrous oxyd, and 52 from the ammonia, which gives after the rate of 28 per cent. of azote in volume on the evolved gasses.

We now proceed to the very interesting researches of Sir H. Davy on the nature of ammonia.

This eminent philosopher, after his most important discovery of the metallic bases of the fixed alkalies, was led from analogy to entertain the opinion that ammonia was probably, like the other alkalies, a compound of some peculiar metallic base and oxygen, and some experiments on the decomposition of ammonia, gave him reason to suppose that the hydrogen and azote evolved, were less than the entire weight of the alkali by about $\frac{1}{11}$, which eleventh part he concluded was the oxygen of the ammonia. This opinion, however, has been satisfactorily refuted by the laborious researches of Henry and Berthollet, just described; so that when ammonia is decomposed simply into hydrogen and azote, it appears that the united weights of these two elements equal the weight of the ammonia decomposed with as much accuracy as can be ever expected from such delicate experiments. This part of the controversy therefore seems to be put at rest, but another and highly curious set of phenomena happened to be discovered at the same time, which deserves particular notice.

Dr. Seebeck, of Jena, discovered in 1808, that when solid carbonat of ammonia is slightly moistened and placed in contact with mercury, and the whole connected with the Voltaic battery so that the mercury communicates with the negative pole and the salt with the positive pole, the mercury speedily becomes as soft as butter, expands in bulk, and has all the appearance of an *amalgam*. This when thrown into water effervesces strongly, the water becomes ammoniacal and the mercury returns to its original state. This experiment was repeated by Dr. Pontin and Professor Berzelius with some variation, and by them communicated to Sir H. Davy,* who immediately pursued the subject with his accustomed skill and ingenuity. His principal experiments are the following: a cavity was made in a piece of muriat of ammonia, and into this a large globule of mercury was introduced. The muriat was slightly moistened and placed on a plate of platina, which was made positive in the circuit of the large battery. The quicksilver was made negative by means of a platina wire. A strong effervescence immediately took place, the globule in a few minutes enlarged to five times its former dimensions, and metallic crystallizations shot from it as a centre round the body of the salt, which, when accidentally broken off from the mass, rapidly disappeared, emitting ammoniacal fumes and reproducing mercury.

When a piece of moistened carbonat of am-

* Phil. Trans. for 1808 and 1809.

monia was used, the appearances were the same, but a black matter formed in the cavity, apparently carbon.

It then occurred to Sir H. Davy that the strong deoxydating power of potassium or of sodium, might be made to produce the same effect on the ammoniacal salt without the intervention of any galvanic apparatus. Accordingly a small portion of potassium was dropped into the globule of mercury contained in the moistened cavity of the lump of muriat of ammonia, and immediately without any further apparatus, the mercury enlarged as before to six or seven times its bulk, and the same amalgam was formed, with this slight difference however, that it appeared to be more permanent, and to retain a portion of the potassium used.

This ammoniacal amalgam at the temperature of 70° or 80° is of the consistence of butter, at the freezing point it crystallizes into small undefined brilliant facets. When exposed to the air it soon becomes covered with a white crust of carbonat of ammonia. When thrown into water it produces about half its bulk of hydrogen, and returns to the state of running mercury, the water becoming ammoniacal. When thrown into muriatic acid gas, it instantly becomes coated with muriat of ammonia, and some hydrogen is disengaged. In sulphuric acid it becomes coated with sulphat of ammonia and sulphur.

The physical properties of this amalgam are very curious. The mercury appears to gain no more than about $\frac{1}{12000}$th of its weight of new matter, but is thereby rendered solid, has its specific gravity diminished from 13.5 to less than 3. and retains its metallic colour, lustre, opacity, and conducting power.

Sir H. Davy made many attempts to obtain a peculiar metallic substance from this amalgam, by distillation, out of the contact of air, and thus to exhibit the supposed basis of ammonia *(or Ammonium)*, in a separate state. But all these attempts failed, for under every circumstance the amalgam, when heated, gave out hydrogen and ammonia, and the mercury returned to its former state. In the most accurate experiments the proportions of these two gasses evolved were two of ammonia and one of hydrogen.

The nature of this amalgam is still very obscure, and much difference of opinion prevails on this subject among chemists. As it seems well ascertained that ammonia is resolvable solely into azote and hydrogen, it follows, that if ammonia is really an oxyd of some metallic base, azote and hydrogen, or one of them, must also be oxyds of some hitherto unknown substance, and this idea has been adopted by M. Berzelius, in his elaborate analytical researches, who supposes both hydrogen and azote to be oxyds of ammonium in different proportions. But when the ammoniacal amalgam is distilled, hydrogen and ammonia both appear, and the source of the hydrogen remains to be accounted for. This Sir H. Davy does, by supposing that as the amalgam is formed from moist substances, sufficient water adheres to it to afford oxygen by its decomposition, whilst its hydrogen unites with the amalgam. Nevertheless an excess of hydrogen is always produced in the distillation of the amalgam, even where the most scrupulous care is taken to exclude moisture.

Before we proceed with the other decompositions of ammonia, we shall relate the experiments of Messrs. Gay Lussac and Thenard,[f] on the ammoniacal amalgam, in which they have repeated the experiments of Seebeck and Davy, and have added other interesting facts. They observe that when the amalgam is formed by the agency of galvanic electricity upon mercury in contact with moistened muriated ammonia, the acid of the salt and the oxygen of the water are carried to the positive pole, round which a dense and suffocating vapour of oxymuriatic acid collects. On the other hand, little or no gas of any kind escapes at the negative pole; but if the mercury is removed, then the effervescence is equally great at this pole also; from which they infer that the mercury simply absorbs the gas that would otherwise have escaped, and forms the amalgam..

When this amalgam is well dried and inclosed in a dry bottle of common air, and simply shaken for a few minutes, it is entirely decomposed, running mercury is produced, and hydrogen and ammoniacal gas are found mixed with the air of the bottle, which is no way altered when examined by Volta's eudiometer. Hence it appears that this amalgam can only exist under the electric influence, and as soon as this is destroyed by agitation, it returns to its elementary state. The amalgam made in Davy's method by mercury, potassium, and muriat of ammonia, without the agency of electricity, is more permanent, and remains in this state as long as it contains any potassium, but as soon as this is destroyed the amalgam is suddenly broken up. A quantity of this amalgam

[f] Recherches Physico-Chimiques faites par M.M.Gay Lussac and Thenard.

was made, and the outer crust being removed by a knife, some of the inner part was taken up by a dry iron spoon, and put into a very dry glass tube inverted over mercury that had just been boiled. The tube being closed with a dry stopper was gently shaken, the amalgam was speedily decomposed, and a considerable quantity of gas was generated, consisting of ammonia and hydrogen in the proportion of about $2\frac{1}{2}$ to 1. The authors say that it is impossible that any moisture should here be present, since this is incompatible with potassium, and hence it appears that the amalgam cannot contain any basis of ammonia (supposing the alkali itself to be an oxyd of some unknown basis) since there is no obvious source from which this basis could abstract oxygen when the ammonia is regenerated. The authors endeavoured to ascertain the respective quantities of ammonia and of hydrogen given out during the decomposition of the amalgam, and they found that the mercury of the amalgam gave about 3.47 times its volume of hydrogen, and 4.22 of ammonia, which together made $\frac{7}{100000}$ of the weight of the mercury.

On the action of Potassium on Ammonia.

When potassium is fused in ammoniacal gas,[g] it is gradually changed into a very fusible olive-green substance, the ammonia disappears entirely, and part of the space which it occupied is filled with a quantity of hydrogen exactly equal to that which the potassium employed would have given, if thrown into water. This experiment may be performed in a bent tube over mercury, but care must be taken to shake off every particle of mercury from the potassium before it is deposited in the bend of the tube. Heat is then applied by a spirit lamp, and soon the potassium melts and becomes covered with a thin crust which directly after disappears, leaving the surface very brilliant, in a few seconds much ammonia is absorbed, and the olive-green substance is produced. By using sufficient ammonia all the potassium is changed to this olive-green matter. The quantity of ammonia absorbed varies from less than 100 to 126 times the bulk of the potassium, according to the heat employed. This olive-green substance is opake, and heavier than water, when heated it melts and disengages ammonia, hydrogen, and azote, and then solidifies, still retaining its green colour. When exposed to the air at a common temperature, it gradually changes to ammonia and potash. When thrown into a heated crucible it suddenly inflames. It burns rapidly when heated in oxygen gas. In water it heats and is immediately decomposed into potash and ammonia. The same effect takes place with acids. When heated with most of the metals, particularly the easily fusible ones, azote, ammonia, and sometimes hydrogen are disengaged, and an alloy of potassium with the metal used is obtained. M. M. Gay Lussac and Thenard examined with much care the effects produced by the application of different degrees of heat to this olive-green matter. The potassium was first put into a glass vessel with a certain quantity of pure hydrogen, to preserve the potassium from the contact of the mercury by which it was confined. Some pure ammoniacal gas was then added, and the whole was heated till the olive-green matter was produced, and when cold the absorption of ammonia was ascertained. The olive-green matter was then heated gradually to redness in the same vessel, without being removed, when it melted, boiled, and finally became solid again, blackish, and was no longer fusible. The remaining ammonia was then absorbed by water, and the azote and hydrogen analyzed in Volta's eudiometer. The general results of several experiments at different degrees of heat was, that as soon as the heat is sufficient to melt the olive-green matter, it begins to give out gas; that as long as the heat does not quite reach a cherry red, the gas is only ammonia; but by raising the heat to low redness, much hydrogen and azote become mixed with the ammonia given out; and at a higher heat, the gas becomes entirely hydrogen and azote, in the proportions of three to one, that is, in which they constitute ammonia; but however long the heat is continued, no more than about three-fifths of the quantity of gas originally absorbed by the potassium is expelled, so that it does not return to the state of potassium, but to a blackish infusible compound.

When this olive-green matter is confined over mercury and a drop of water is let up to it, much heat is excited, and a good deal of gas generated. By carefully adding water as long as any gas is generated, and assisting the process by a gentle heat, the whole is converted into a lump of moist solid potash and pure ammoniacal gas; and it was found that the ammonia obtained was almost equal to that which had been originally absorbed by the potassium, during its conversion into the olive-green matter, the slight difference in quantity

[g] Recherches Physico-Chimiques, faites par M. M. Gay Lussac and Thenard.

being attributed to the ammonia absorbed by the moistened potash.

Sir H. Davy has also made a number of experiments on this singular compound with results some of which agree with those of Messrs. Gay Lussac and Thenard, and others differ from them. Some of these we shall mention,[h] particularly the properties of the residuum of the olive-green substance after it has been heated to redness.

Its colour is black and in lustre it resembles plumbago. It is opake, and brittle. It is a conductor of electricity. It does not fuse at a low red heat, but gives out a dark coloured sublimate. When exposed to the air at a common temperature it usually takes fire immediately and burns with a deep red light. When it is acted upon by water it heats, effervesces violently, and is resolved into ammonia and potash, with a little inflammable gas. It has no action upon quicksilver. It combines with sulphur and phosphorus by heat, and these compounds when wetted inflame and give out, the one sulphuretted, and the other phosphuretted hydrogen gas.

On distilling this substance in a tube of wrought platina in a very intense heat, potash was found with a quantity of potassium in the tube, and the gas was hydrogen with only a small proportion of azote.

The remarkable circumstance of this experiment is the deficiency of azote, this substance being in much less proportion than is required to constitute ammonia if the analysis of this alkali by electricity be at all correct.

After all that has been done on the analysis of ammonia, no satisfactory proof has yet been given that it can be decomposed into any other elements than azote and hydrogen.

AMMONIAC. (Gum.)

This gum has been examined by M. Braconnot.[a] Exposed to a very gentle heat it loses 6 per cent. of its weight of mere moisture. Distilled *per se*, it yields half its weight of a brown empyreumatic oil containing ammonia. The coal contains phosphat and carbonat of lime.

Twenty five grammes of gum ammoniac were boiled with alcohol. The whole was dissolved except 5.8 grammes, and the solution remained clear on cooling. The insoluble portion was heated with water and the greater part dissolved, leaving however a grey glutinous mass insoluble both in water and spirit of wine.

The watery solution left a gum on evaporation, which was transparent, reddish yellow, slightly bitter, and brittle: water easily dissolves it. It is abundantly precipitated by Goulard's extract, (but *not* by the acetite of lead) and only very partially by the nitrate of mercury and of lead. Lime water does not alter the solution, but oxalat of ammonia separates some oxalat of lime.

The resin produced by the evaporation of the alcoholic solution of gum ammonia is reddish yellow, transparent, brittle, but easily softens between the fingers. It has no taste. It unites with the alkalies with ease, even without heating, and the result is a saponaceous bitter solution.

Sulphuric acid dissolves the resin quietly in the cold, and the solution is separated by water.

When nitric acid is heated on this resin, it is suddenly decomposed with much red vapour. On evaporating the liquor to dryness a bitter resin is obtained which melts at a low heat, unites to alkalies, dissolves in alcohol and in water, and precipitates in part from the latter if it has been used boiling. Cold water also dissolves much of this bitter resin, giving a very beautiful yellow colour that stains the fingers strongly, and fixes itself easily and most firmly to silk and wool, so as to become unalterable by oxymuriatic acid, and even by alkalies if weak.

Gum ammoniac contains 18.4 per cent. of gum; 70. of resin; 4.4 of matter resembling gluten; and 6 of moisture.

AMPHIBOLE.

At the end of the article of Strahlstein it is remarked that a strong analogy subsists between the several varieties of Hornblende, Actynolite, Tremolite, and Asbestus. M. Hauy has since, in his *Tableau comparatif*, entered into an interesting discussion of this question, and from crystallographical resemblances, aided by the results of recent chemical analysis, has arranged them in the following manner.

The Labrador Hornblende forms a species by itself, under the name Hypersthene. The resplendent Hornblende (Schillerspath or Bronzite) forms a variety of Diallage, the *metalloide*. A few of the Strahlsteins constitute the species Epidote, (Thallite of Karsten) the remainder of the Hornblendes and Strahlstein, and all the Tremolites are included under the species Amphibole. Asbestus for the present ranks as a distinct species, but M. Hauy cites with evident favour the opinion of Cordier, who is for including it under Amphibole.

The following are the essential crystallographical characters of amphibole. Its primitive crystalline form is an oblique rhomboidal prism,

[h] Phil. Trans. for 1809.

[a] An. Chem. tom. 68.

the lateral planes of which unite under angles alternately of 124° 3[illegible] and [illegible] 26': and the ratio between the height of the prism and the diagonal passing through the obtuse angles of the summit is nearly as one to four.

The following are some of the most recent analyses.

Basaltic Hornbl. by Klapr.	Crystall H. from Cape de Gate, by Laugier.	Lamellar Hornbl. by Klapr.	Actynolite of Zillerthal, by Laugier.	
47.	42.	42.	50.	Silex
8.	9.8	11.	9.75	Lime
2.	10.9	0.	19.25	Magnesia
26.	7.69	12.	0.75	Alumine
15.	22.69	32.	11.	Oxide of Iron
	1.15 Oxide of Manganese		5.	Oxide of Chrome
98.	94.23	97.	95.75	

Fibrans Tremolite, by Klapr.	Comm. Tr., by Lowitz.	Grey Tremolite, by Laugier.	Baikalite, by Lowitz.	
65.	52.	50.	44.	Silex
18.	20.	18.	20.	Lime
10.33	12.	25.	30.	Magnesia
0.16	0.	0.	6.	Oxide of Iron
6.5		5.		Water and Carbonic acid
	12.			Carbonate of Lime
99.99	96.	98.	100	

ANALCIME. Cubic Zeolite J. Wurfel Zeolith W.

It occurs limpid, or greyish-white; is amorphous, mammillated, radiated, or crystallized. Its form is a cube either perfect or with similar modifications round all the solid angles, producing symmetrical varieties that distinguish it from other species with which it might be confounded. It has rarely any natural joints visible, hence its fracture is compact conchoidal. It varies from translucent to transparent; usually scratches glass. sp. gr. 2.0.

Before the blowpipe it intumesces like borax and melts into a glass, emitting at the same time a phosphoric light. It is composed according to Vauquelin, of

58.	Silex
18.	Alumime
2.	Lime
10.	Soda
8.5	Water
96.5	
3.5	Loss

Var. 1. Sarcolite

Colour flesh red, opake, somewhat softer than the preceding: consists, according to Vauquelin, of

50.	Silex
20.	Alumime
4.25	Lime
4.25	Soda
20.	Water.
98.5	
1.5	Loss

Analcime occurs chiefly in the glands of amygdaloid, and other trap rocks.

ANALYSIS OF VEGETABLE AND ANIMAL MATTER.

In an interesting memoir on this subject by Messrs. Gay Lussac and Thenard,[a] these chemists shew the great difficulties and the many causes of inaccuracy that attend the usual modes of analyzing vegetable and animal matter, and describe a new method of proceeding, by which they consider that they have been able to combine the carbon and hydrogen with the ut-

[a] Recherches, &c. tom. 2.

most quantity of oxygen with which they can unite, and thus by proper data to estimate the proportion of these constituent parts, and of oxygen, existing in the substance analyzed. The substance selected to oxygenate these elements is the oxymuriat of potash, and the matter to be analyzed is mixed with this salt and deflagrated in an apparatus contrived for the purpose, consisting of a thick glass tube set vertically in a fire with a lateral tube to conduct the generated gasses to a mercurial trough, and a cock above, the stopper of which is not perforated, but contains a small depression, into which a portion of the material to be analyzed is put, and by turning the cock downwards, this portion falls into the heated tube, and there deflagrates. The proportion of the oxymuriat requisite to burn completely the substance analyzed is found by previous trials in an open crucible, so much of the salt being required, that the residue after deflagration shall be quite white, or at least not carbonaceous; and in the actual experiment a considerable excess of the oxymuriat is employed. The materials are then accurately weighed (after being long dried at a boiling-water heat) and mixed in a mortar with a little water to an adhesive mass, which is divided by being thrust into a brass mould, and the pieces are rolled up by the fingers into little balls that they may drop clean from the stopper of the cock down into the deflagrating tube. These balls are again dried at the same heat before using.

The oxymuriat of potash is previously analyzed by itself in a proper apparatus to ascertain the proportion of oxygen which it furnishes, and to ensure an uniformity in this agent a considerable quantity of the salt is fused and then rubbed to powder by itself and kept for use. If the substance to be analyzed is a vegetable acid, it is combined with lime or barytes before mixture with the oxymuriat; and this calcareous or barytic salt is separately analyzed, and the carbonic acid that remains united with the earth after deflagration is properly estimated.

The earthy or other incombustible matter belonging to the substance to be examined is also separately estimated by calcining this substance by itself in a platina vessel and lixiviating the residue. The author gives at length all the precautions required in the management of the apparatus, both in preparing for the deflagration and in the estimation of the gasses produced. These last are supposed to be only carbonic acid, azote, and oxygen, the quantity of the oxymuriat being more than sufficient to convert into water all the hydrogen of the substance analyzed. The probability of a little carburetted hydrogen having escaped combustion is also acknowledged, and some allowance is made for it, though apparently not in a very accurate way. The examination of the gasseous products of the deflagration is therefore thus conducted: 200 measures of the gas (standing over mercury) are added to 40 measures of pure hydrogen, and detonated by the electric spark. By this means the excess of oxygen is separated in the form of water, and the quantity of this excess is, of course, one third of the volume of the entire absorption after the electrization. The carbonic acid is absorbed by potash, and the residue is further examined for oxygen by the same means, and the ultimate residue is considered as azote. The data therefore from which the results of the analysis are made out are these: the proportion of combustible matter in the substance examined is previously found by calcination of another portion of the same; the actual quantity of oxygen employed in the deflagration is known by that of the oxymuriat used; the carbonic acid is absorbed by potash and its carbon estimated; the excess of oxygen is found by subsequent detonation with hydrogen; the hydrogen of the substance is presumed to form water with all the oxygen unaccounted for; and the azote exists in the residual azotic gas.

Fifteen vegetable substances were analyzed in this way, the particulars of some of which we shall give, and the results of the whole at the end of this article.

Sugar. 1000 parts of white sugar candy, exposed for many hours to a boiling water heat, lost only 8 parts of moisture. Some of the same sugar when calcined left only $\frac{1}{1000}$ of residue. The quantities used for the experiment were 300 parts of sugar (exclusive of the moisture and insoluble residue) and 7 times as much oxymuriat of potash, the oxygen of which was 627 parts (by weight). This oxygen was recovered, all but two parts, in 449.9 parts of carbonic acid containing 322 of oxygen, and in an excess of 303. of oxygen discovered by detonation with hydrogen. Therefore the 300 of sugar had in fact only consumed 322 of oxygen, all of which went to form carbonic acid, of which the carbon was 127.1; and as no other product from the sugar but carbonic acid and water appeared, it would follow that sugar is composed of 42.47 per cent. of carbon, and 57.53 of water, either as such, or as oxygen and hydrogen in the exact proportions required to form water.

Gum Arabic, Starch, Sugar of Milk, Oak and Beech Wood, all agree with sugar in being composed merely of carbon, and of oxygen and hydrogen in the proportions required to form water.

Mucous Acid. This acid was prepared by heating sugar of milk with nitric acid. The solution soon became turbid, and much mucous acid was deposited, which was well washed and dried in a boiling water heat. This acid left no residue whatever after calcination. On deflagrating a given portion of it with four times its weight of oxygen in the above-mentioned apparatus, and estimating the oxygen and carbonic acid of the product, a considerable excess of oxygen above the quantity required to form water with the hydrogen of the mucous acid was found, and hence the acid is considered as composed of carbon, water, and oxygen in excess.

Oxalic Acid. This acid was not mixed immediately with the oxymuriat of potash, but was first combined with lime (by being saturated with ammonia and precipitated by muriat of lime) and the dried oxalat of lime was calcined by itself in a platina crucible, and thus found to consist of 61.345 of acid and 38.655 of lime.

A given portion of the oxalat of lime was then deflagrated in the usual way with 1½ its weight of the oxymuriat, and the results analyzed as before, but as a portion of the carbonic acid was retained in the deflagrating tube united with the lime and muriat of potash, this was separately analyzed by muriatic acid and the carbonic acid expelled.

Tartareous Acid. This acid was extracted in the usual way from tartrite of lime by sulphuric acid, but as it still retained a little of this latter acid even after repeated crystallization, it was dissolved in water and boiled with powdered litharge added gradually till the liquor no longer precipitated nitrat of barytes, by which means all the sulphuric acid was got rid of. The lead in solution was then separated by a current of sulphuretted hydrogen gas, and the clear liquid when evaporated gave pure tartareous acid. It was found impracticable however to make it into balls with oxymuriat of potash and water, as it deliquesced instantly on exposure to air.

The acid was therefore combined with lime, the tartrite of lime, dried at 212°, was found by calcination to consist of 77.577 of acid and 22.423 of lime, and this was further analyzed in the same manner as the oxalic acid.

Citric Acid. This was analyzed exactly as the preceding acid. The citrat of lime consisted of 68.83 of acid and 31.17 of lime.

Acetic Acid. The acid here employed was first expelled from acetite of potash by sulphuric acid, and then heated with an excess of carbonat of barytes and the acetite of barytes evaporated and dried. But as this acetite could not be analyzed by simple calcination, (no continuance of heat being able to expell from the barytes all the carbonic acid formed by the combustion of the acetous) 30 grammes of the acetite were decomposed by sulphat of ammonia, and the sulphat of barytes was transferred, while still wet, to a platina crucible, and gradually ignited, till all the sulphat and acetite of ammonia adhering to it were expelled, and the sulphat of barytes remained pure. It weighed 25.443 grammes and contained 67 per cent. of barytes; and from these data acetite of barytes dried at 212°. consists of 43.17 acid and 56.83 barytes. This acetite was then deflagrated as the last, and the results examined.

All the acids here examined contained a notable excess of oxygen, as will be seen in the tabular statement at the end of this article.

Resin of Turpentine, or *Common Rosin.* This was simply mixed with 12 times its weight of the oxymuriat and deflagrated in the apparatus. Scarcely any carburetted hydrogen was produced by the combustion, but carbonic acid, and much water, which last when collected and examined was neither acid nor alkaline, and the residue in the tube was pure muriat of potash. The large quantity of water produced indicated a proportional excess of hydrogen in the resin, so that by the usual mode of estimation this resin contained carbon, oxygen and hydrogen in the proportions for constituting water, and an excess of hydrogen.

Copal, Wax, and *Olive Oil*, were analyzed in the same manner, some little difference being observed in the manipulation of mixing them with the oxymuriat.

From the analysis of the above fifteen vegetable substances the authors consider that the following important inferences may be deduced, namely:

That a vegetable substance is acid whenever the oxygen which it contains exists in a larger proportion than will constitute water with the hydrogen present.

That a vegetable substance is resinous, or oily, or alcoholic, &c. when the oxygen is in less proportion than is required to form water with the hydrogen.

That when the oxygen and hydrogen are in the exact proportions in which they constitute water, the vegetable substance is analogous to sugar, gum, fecula, ligneous fibre, &c.

The analysis of some of the primary *animal* substances was then undertaken. In this case there is another element, azote, which requires particular notice. Whenever any animal matter is deflagrated with an *excess* of oxymuriat of potash, a quantity of nitrous acid gas is formed, which is the greatest where the heat required for combustion is the lowest. This circumstance would render the analysis in the way above described much more complicated and uncertain, unless some method could be found of preventing the formation of nitric acid. This the authors assert is effectually done by lowering the dose of the oxymuriat, so that with this, neither ammonia, nor nitric acid is produced, but the whole products are azotic gas, water, carbonic acid, and oxycarburetted hydrogen, and with proper precautions even the latter compound may be almost entirely prevented, and nearly the whole of it changed to carbonic acid and water. The requisite proportions of oxymuriat of potash and the animal matter employed must be found by previous trials with successive quantities. The animal matter, long dried at 212°, must be mixed thoroughly, first with thrice its weight of the oxymuriat and thrown into a crucible barely red-hot. If the residue of the deflagration is black it will shew that there is too little oxymuriat, if it is white the quantity of this salt may be too much, if it is greyish the proportions are sufficiently correct; or at any rate neither nitric acid nor ammonia will be produced in the deflagration, though perhaps there will be some carburetted hydrogen. Whenever any gas contains along with this gas a certain proportion of azote and carbonic acid gas, the presence of these will prevent the entire combustion of the carburetted hydrogen with any oxygen that may be added. It will therefore be necessary to add a small quantity of pure hydrogen to produce the detonation of the carburetted hydrogen, and its total conversion into carbonic acid and water.

Fibrine. The fibrine collected from ox-blood by stirring it as soon as drawn, was dried by long exposure to boiling-water heat; and a portion of it calcined by itself left only $\frac{1}{80}$ of fixed matter. Another portion was then mixed by long trituration with moist oxymuriat of potash, then made into balls and deflagrated in the same manner as the vegetable substances. The flame was very intense, and much water condensed in the cooler part of the apparatus. The residue in the red-hot tube was a white saline mass consisting only of muriat of potash with the incombustible part of the fibrine. The results after subsequent analysis gave for the constituents of fibrine, carbon, oxygen and hydrogen in the proportions of water, some excess of hydrogen, and azote. The exact quantities will be found in the table.

Albumen from white of egg, *Caseum* or the pure cheese of milk, and *Gelatine* were analyzed exactly in the same way, except that the oxymuriat was added to the gelatine in solution (its proportion of dry gelatine being known) and both were dried together by boiling-water heat, this being the only way in which the two could be intimately mixed.

The general result of the analysis of these four animal substances is; that they all contain even more carbon than sugar or gum does, that in all the hydrogen exceeds the proportion required to form water with the oxygen present, and that the azote also found is not far from the proportion required to form ammonia with the excess of hydrogen. Hence (supposing the small differences to arise from the unavoidable errors in the practical part of the experiments) it is not unlikely that these animal substances might be resolved into carbon, water and ammonia. In this point of view these animal matters will bear a strong analogy with sugar, mucilage, &c. inasmuch as each consists of carbon, and other constituent parts in the exact proportion in which they will unite into some definite compound, being carbon and water in the vegetable substances; and carbon, water, and ammonia in the animal.

The authors have not carried their experimental research further, but they suggest the probability of further analogies between the vegetable and animal principles in the animal acids and animal oils.

We shall not give the general observations which are suggested to the authors of these important experiments, but shall only add the tables of the actual results. It will be understood that the substances analyzed are taken, exclusive of their incombustible earthy metallic and saline contents, and that no azote is considered as entering into the vegetable principle. In the animal substances all the hydrogen and azote are estimated as constituting ammonia, allowing some excess or deficiency of this principle, to be attributable to accidental errors in the experiments.

Table of the constituent parts of the following Vegetable Substances.

Substance analyzed. 100 parts	Carbon.	Oxygen.	Hydrogen	Or supposing the Hydrogen and Oxygen to form water. Carbon.	Water.	Oxygen in excess.
Sugar	42.47	50.63	6.90	42.47	57.53	0
Gum Arabic	42.23	50.84	6.93	42.23	57.77	0
Starch	43.55	49.68	6.77	43.55	56.45	0
Sugar of Milk	38.825	53.834	7.341	38.825	61.175	0
Oak wood	52.53	41.78	5.69	52.53	47.47	0
Beech wood	51,45	42.73	5.82	51.45	48.55	0
Mucous Acid	33.69	62.67	3.62	33.69	30.16	36.15
Oxalic A.	26.57	70.69	2.74	26.57	22.87	50.56
Tartareous A.	24.05	69.32	6.63	24.05	56.24	20.71
Citric A.	33.81	59.86	6.33	33.81	52.75	13.44
Acetic A.	50.22	44.15	5.63	50.22	46.91	2.87
						Hydrogen in excess.
Rosin	75.94	13.34	10.72	75.94	15.16	8.90
Copal	76.81	10.61	12.58	76.81	12.05	11.14
Wax	81.79	5.54	12.67	81.79	6.30	11.91
Olive Oil	77.21	9.43	13.36	77.21	10.71	12.08

Table of the constituent parts of the following Animal Substances.

Substance analyzed. 100 parts	Carbon.	Oxygen.	Hydrogen	Azote.	Or, supposing the Oxygen to form Water with part of the Hydrogen, and the remainder of the Hydrogen to form Ammonia with the Azote. Carbon.	Water.	Ammonia	Azote, excess or deficiency.
Albumen	52.883	23.872	7.540	15.705	52.883	27.127	23.182	—3.191
Caseum	59.781	11.409	7.429	21.381	59.781	12.964	31.778	—4.623
Gelatine	47.881	27.207	7.914	16.998	47.881	30.917	22.743	—1.541
Fibrin	53.360	19.865	7.021	19.934	53.360	22.369	23.463	+0.808

ANDALUSITE. Feldspath Apyre H. Its colour is flesh red verging on rose red. It occurs massive and crystallized in rectangular prisms. Its fracture is imperfectly foliated; the natural joints are parallel to the sides of a nearly rectangular prism, and to one of the diagonals of its transverse section. It is translucent; is harder than quartz, and sometimes even than spinelle. Sp. gr. 3.1.

It is infusible before the blow-pipe without addition. It is composed, according to Vauquelin, of

52.	alumine
38.	silex
8.	potash
2.	oxide of iron
100.	

This mineral in its crystalline form approaches very near to felspar, and in its analysis differs only in containing an excess of alumine; to this excess its hardness and infusibility are no doubt to be attributed. It was the opinion of Count Bournon (and M. Hauy seems inclined to agree with him) that andalusite is felspar intimately mixed with corundum.

It occurs in granite in Spain, France, Saxony, Ireland, and Devonshire.

ANTHOPHYLLITE.

This mineral has a perfectly foliated structure, and though not crystallized, is divisible in the direction of its natural joints, parallel to the sides of a rectangular prism; two of these sections present brightly shining surfaces, and are much more easily obtained than the others. Besides these four joints two others may be perceived on close inspection with a bright light, dividing the prism diagonally. Its specific gravity is 3.2. Its hardness is about equal to that of glass. Its colour is brownish, with more or less of a pseudo-metallic lustre. It affords by analysis, according to M. John,

62.66	silex
13.33	alumine
4.0	magnesia
12.0	oxide of iron
3.25	oxide of manganese
1.43	water
96.67	

ANTIMONY.

§ 1. *Ores of.*

Red Antimony.

This substance was supposed to be a native kermes or hydrosulphuret of antimony, but, according to a recent analysis by Klaproth,[a] it affords

67.5	antimony
10.8	oxygen
19.7	sulphur
98.0	

Native Antimony.

A specimen of this substance from Andreasberg in the Hartz, has been analysed by Klaproth,[b] with the following result:

98.	antimony
1.	silver
0.25	iron
99.25	

White Antimony.

A specimen of this mineral in quadrilateral tabular crystals, from Przibram in Bohemia, was analysed by Klaproth,[c] with the especial object of ascertaining whether it contained any muriatic acid as had been suspected by Hacquet. For this purpose 25 grs. of the mineral were fused with 200 grs. of carbonated potash: the mass was then digested in water and the alkali was supersatuturated by nitric acid. On the addition of nitrate of silver no precipitation took place, hence the white antimony may be considered as a pure oxide of antimony.

Antimony with Nickel.

This ore has hitherto been found only in a mine at Treusberg in Nassau.[d] It is composed in part of broad parallel plates of a shining white, resembling antimony, and in part of a compact leaden grey substance with a glimmering lustre. Its sp. gr. is 5.65. Its hardness is superior to that of grey antimony. When exposed on charcoal to the action of the blowpipe it melts readily, and disengages white vapours of an arsenical odour, and which more or less adhere to the charcoal in form of a yellowish powder; by degrees the globule becomes less fusible, and there remains behind a white brittle refractory button.

By digestion in nitric acid a portion of the ore is converted into a yellowish white voluminous powder, and the remainder combines with the menstruum into a green liquor.

The powder, by digestion in muriatic acid slowly dissolves, with the exception of a small residue of a yellowish colour which consists of sulphur, of sand, and of a little arseniate of iron. This solution when diluted with water lets fall a white precipitate consisting of muriate of antimony and oxide of arsenic, inseparable from each other with perfect accuracy, according to Vauquelin, by any known chemical process, but in a considerable degree decomposable by distillation with sulphur which raises the principal part of the arsenic in the form of realgar. What remains in the retort is sulphuret of antimony with a little arsenic and lead.

The green nitric solution contains nickel, arsenic, and a little lead.

From the result of this examination, and from the different degree of fusibility exhibited by different portions of the ore, it is considered by Vauquelin as a mixture of sulphuret of antimony, of arsenical nickel, a little galena and iron pyrites.

[a] Klapr. Ess. ii. 147. [b] Ann. de Chim. lxxiii. p. 229. [c] Ann. de Chim. lxxxv. p. 26.
[d] Hauy tab. comp. 299. Klap. Ess. ii. 142.

The same ore has since been subjected to a careful analysis by Klaproth.[a]

1. 300 grs. separated as accurately as possible from the oxide of iron with which it is naturally mixed, were digested in cold aqua regia, composed of 5 parts muriatic acid and 1 part nitric. The undissolved residue was again subjected to the same process, after which what remained undissolved was well washed in alcohol and dried. Its weight was 51 grs. of which 41 grs. burnt off with all the appearances attending the combustion of sulphur, leaving behind 10 grs. which dissolved entirely in aqua regia.

2. The solutions were mixed together in a retort and much concentrated; water being then added a copious precipitate fell down. The supernatant liquor was again concentrated, and a second precipitate was obtained as before by the addition of water.

3. After separating the precipitate the fluid was again concentrated, and appeared of a grass-green colour; ammonia was then added in excess which threw down a brown oxide of iron weighing after calcination 13.5 grs.

4. The ammoniacal solution was evaporated to dryness, and the saline mass gently ignited; the residue which had the appearance of yellowish brown micaceous scales was digested in muriatic acid, in which it entirely dissolved. By means of caustic potash a precipitate of an apple-green colour was obtained, which by calcination left behind 93.25 grs. of pure oxide of nickel of a slate grey colour, indicating 70.75 grs. of metallic nickel.

5. The precipitate N° 2, proved on examination to be arseniate of antimony, but all attempts at an accurate decomposition of it were fruitless.

Thus foiled, M. Klaproth had recourse to the following method. 200 grs. of the levigated ore were ignited with 600 grs. of nitre; the mass was then lixiviated and well washed. The lixivium on being slightly acidulated with nitric acid gave no precipitate, a proof that no antimony had been taken up. Lime water was then added and a voluminous precipitate of arseniate of lime fell down. This latter after being washed and dried was mixed with one-third of its weight of charcoal and sublimed in a retort, and afforded 22 grs. of metallic arsenic.

The matter insoluble in the lixivium was digested in aqua regia in which it dissolved almost entirely, and from this solution water threw down a precipitate weighing 116 grs. equivalent to 89 grs. of metallic antimony.

Hence the constituent parts of this mineral, omitting the oxide of iron which is considered by M. Klaproth as accidental, are

25.25	metallic nickel
47.75	——— antimony
11.75	——— arsenic
15.25	sulphur
100.	

§ 2. *Chemical Properties.*

Much difference of opinion has arisen with regard to the number and composition of the oxyds of antimony. Thenard reckons as many as six, Proust only two. According to the latter chemist the lowest oxyd or *suboxyd* is composed of 81.5 metal to 18.5 oxygen or 22.7 oxygen upon 100 of metal; and the highest oxyd or *peroxyd* contains 77 metal to 23 oxygen; or 29.87 oxygen upon 100 of metal

Pr. Berzelius reckons four oxyds of antimony, two of which have the characters of acids. We have not the particulars of the experiments, but the following are stated as the results:[a]

The first or lowest oxyd is obtained by exposing antimony to the action of the positive side of the voltaic pile. It is grey, and when in contact with acids that do not themselves impart oxygen, part of the oxyd returns to the metallic state, and the rest passes to the second oxyd and dissolves.

The second oxyd is the base of emetic tartar, and most of the other antimonial salts. This is white and fusible.

The third oxyd is also white but infusible at a white heat. It possesses all the characters of an acid, and is called by the author *Stibious Acid.* The white oxyd of antimony by nitre is in fact a salt composed of potash with an excess of this stibious acid, and is decomposed by boiling water into a neutral soluble stibiate of potash, and an insoluble portion with still greater excess of acid. From this soluble stibiate of potash professor Berzelius has formed many other neutral stibiates.

The fourth oxyd is straw coloured and is an acid with higher oxydation than the former, and therefore has the name of *Stibic Acid.* At a high temperature it gives out oxygen and passes to the state of *Stibious Acid.*

[a] Klapr. Ess. ii. 134.

[a] An. Chim. tom. 83, p. 169.

The respective proportions of metal and oxygen in these compounds are the following.

The second oxyd contains 100. antimony to 18.6 oxygen.

The third oxyd contains 100. antimony to 27.9 oxygen.

The fourth oxyd contains 100. antimony to 37.2 oxygen.

These three oxyds therefore have their oxygen in the proportions of 1, $1\frac{1}{2}$ and 2.

The elements of the first oxyd are not given. It may be presumed (according to the theory of definite proportions) to contain either 9.3 or $\frac{9.3}{2} = 4.65$ oxygen to 100. of metal.

The same author also gives for the elements of the sulphuret of antimony, 100. of antimony to 37.25 of sulphur.

Tartarized Antimony.—Tartar Emetic. A very elaborate examination of this salt and of the various modes of preparing it, has been given by a practical chemist, Mr. R. Phillips, [b] who has shewn the great uncertainty of success in following the mode laid down by the London College of Physicians in their last Pharmacopœia. This uncertainty arises from the strong tendency in this metal to pass from the state of suboxyd (in which alone it is soluble in tartar) to that of insoluble peroxyd. Mr. Phillips has given as an improvement in the process, the employment of the sub-sulphat of antimony as the base to be afterwards boiled with a solution of an equal weight of cream of tartar, which crystallizes with the tartar into the tartarized antimony, or triple tartrite of antimony and potash. The sub-sulphat is prepared by boiling and evaporating to dryness a mixture of sulphuric acid with about half its weight of metallic antimony, and afterwards washing out of the residue all the uncombined sulphuric acid, leaving a tasteless sub-sulphat, in which the oxyd must be at a low state of oxydation, since it dissolves copiously with tartar and forms with it the tartar emetic. As all tartar contains tartrite of lime, some sulphat of lime is also produced by the acid of the sub-sulphat, which partly crystallizes along with the emetic tartar, but is separated by a second solution.

APLOME.

This mineral occurs in rhomboidal dodecahedrons of a deep brown colour inclining more or less to orange, striated externally parallel to the short diagonals of the rhombs. On exposing fragments of this substance to a bright light, indications of lamina may be perceived, the direction of which, combined with that of the striæ, affords reason for supposing that its primitive form is a cube. Its specific gravity is 3.44. It scratches quartz though slightly. Its fracture is uneven, passing into small conchoidal with a moderate lustre. It is opake and in very minute crystals translucent. Before the blow-pipe it is fusible into a blackish glass. It affords by analysis, according to Laugier,

40.	silex
20.	alumine
14.5	oxyd of iron
14.5	lime
2.	oxyd of manganese
2.	ferruginous silex
2.	volatile matter
95.0	

It occurs in Siberia on the banks of the river Lena.

APOPHYLLITE. See ICHTHYOPHTHALMITE.

ARCTIZITE. See WERNERITE.

ARENDALITE. See STRAHLSTEIN, glassy.

ARGIL, native.

A small portion of this mineral, not sufficient for a regular analysis, was examined by Fourcroy, who states it to contain about 24 per cent. of sulphate of lime (Ann. de Mus. I. 45); since which it has been formally analyzed by M. Simon of Berlin, and by Bucholz, with the following results. [a]

Simon.		Bucholz.	
32.5	—	31.0	alumine
19.25	—	21.5	sulphuric acid
0.45	—	2.0	oxyd of iron
0.35	—		lime
0.45	—		silex
47.	—	45.	water
100.00	—	99.5	

ARSENIC.—ARSENICATED HYDROGEN. ARSENIATS.

§ 1. *Ores of Arsenic.*

Mispickel.

Some recent experiments on this ore have been made by M. Chevreul. [b] When mispickel is heated in a glass retort, there rises a sublimate consisting of metallic arsenic with a very small portion of orpiment, and the residue

[b] Experimental Examination of the Pharmacopœia.

[a] Klapr. Dict. Chim. art. *Alumine native.*

[b] Journ. des Mines, xxix. p. 459.

consists of sulphuret of iron, retaining some traces of arsenic. The component parts of this ore, as deduced from a separate analysis of the sublimate and of the residue, are

43.418	arsenic
34.938	iron
20.134	sulphur
98.490	

Iron is well known to have a stronger affinity for sulphur than arsenic has, and as in the present instance the proportion of iron and sulphur is just sufficient to form the sub-sulphuret, it appears probable that mispickel is a combination of iron pyrites and of metallic arsenic.

Arsenical Pyrites.[c]

The primitive form of this substance is a strait rhomboidal prism, the angles of which are alternately 111°-18′ and 68°-42′.

It is composed, according to Lampadius, of

58.9	iron
42.1	arsenic
101.0	

§ 2. *Chemical Properties.*

It is often desirable to detect minute quantities of arsenic mixed with other substances. Some of these means have been already mentioned under this article, (*Ch. Dict. I. p.* 105,) but another should be noticed on account of the great extent of its operation. It consists in first dissolving the arsenic in water, adding a small quantity of sub-carbonat of potash, and then applying nitrat of silver. The process is thus described by Mr. Hume who first suggested it.[d] Put in a glass flask two or three grains of the powder suspected to be arsenic, add eight ounces of distilled water and gradually bring it to boil over a lamp or clear fire. Then add a grain or two of sub-carbonat of potash or soda, and shake the mixture. When clear, pour some of the solution into a glass, and dip just under the surface of the liquid a stick of lunar caustic, and a beautiful yellow precipitate will appear, which can hardly be confounded with any other substance.

Dr. Marcet[e] has given a variation of this process which has the advantage of being performed in a few seconds. Pour some of the clear fluid suspected to contain arsenic into any glass vessel, stir into it a glass rod dipped in pure ammonia, and immediately after another glass rod wetted with nitrat of silver. The same orange yellow precipitate will immediately appear. Care should be taken to add only a very small quantity of each of the reagents, particularly of the ammonia. In either mode it is obvious that any muriatic acid present will give a precipitate with nitrat of silver, and this metallic salt will also be decomposed by the carbonated potash or soda where this method is used, so that it is not the mere appearance of any precipitate, but of an *orange-yellow* precipitate that will determine the presence of arsenic. Where the arsenic is in the state of arsenic acid the colour of the precipitate will be brick-red.

This precipitate is a compound of oxyd of silver and arsenic, either partially or entirely oxydated, and when heated *per se*, especially on charcoal, the arsenic sublimes and leaves a globule of pure silver.

Orpiment and Realgar. The following distinctive characters of these substances are given by M. Thenard.[f]

Both of them melt and sublime unaltered in close vessels and without giving out any sulphureous acid. Both are acted on by the sulphuric nitric and oxymuriatic acids. Sulphuric acid acts much more easily on orpiment than on realgar. In both cases sulphureous acid and arsenious acid are formed, but more of the former acid and less of the latter are produced with orpiment than with realgar. Nitric acid is easily decomposed even without heat on both these substances, and sulphur and arsenious acid are formed. The fixed alkalies dissolve both without heat; when potash is used, hydro-sulphuret of potash and arsenite of potash are formed, for on adding lime-water to the solution a copious white precipitate appears, which, when treated with carbonat of potash, gives a liquid that yields abundance of arsenious acid on saturation with muriatic acid and evaporation.

Sulphur fused with realgar converts it into orpiment, and arsenic added to orpiment changes it to realgar. Three parts of sulphur and four of arsenic form orpiment: and one part of sulphur with three of arsenic form realgar. The latter is the most fusible of the two. Orpiment made artificially by sublimation is

[c] Hauy. Table Comp. 95, 272. [d] Phil. Mag. vol. 33. [e] Medico-Chirurgical Transact. vol. 2, p. 15, and vol. 3. 343. [f] An. Chim. No. 177. p. 284.

yellow and transparent as is native orpiment after being melted; but both assume a very bright clear yellow when reduced to powder. The orpiment produced in the moist way by a soluble arsenite, a hydro-sulphuret, and an acid, is always of the same opake bright yellow as the other orpiment when pulverized.

Arsenic Acid. Arsenious Acid. Arsenite, and Arseniate of Lead.

According to the experiments of Proust, 100 parts of arsenic combine with 33 of oxygen to form the white oxyd, or the *Arsenious Acid*, and with 53 of oxygen to form the *Arsenic* acid. This subject has been examined by professor Berzelius with the view of accommodating these numbers to the system of definite proportions explained under the article Affinity in this appendix. It is there assumed that when any base is capable of more than one degree of oxygenation, the lowest number multiplied by 2, 3, &c. or by the intermediate halves $1\frac{1}{2}$, $2\frac{1}{2}$, &c. will give all the other degrees. Hence the oxygen of arsenious acid must bear one or other of these proportions to that of arsenic acid. Another rule is, that when a compound consists of two oxydated substances the oxygen of the base must bear an equally definite proportion with that of the acid; hence in any of the metallic arseniats (arseniat of lead for example) the oxygen of the arsenic acid must bear a definite and simple proportion to that of the oxyd of lead. Both these questions are here examined.[a]

Arsenious acid contains, according to Proust, 33.33 of oxygen to 100. metal, and arsenic acid contains 53 oxygen to 100. metal, and other chemists give rather less. The nearest definite proportion between these is $1\frac{1}{2}$ times 33, which gives 50. The following are professor Berzelius's experiments.

200 parts of sub-oxyd of lead dissolved in nitric acid, evaporated to expell the excess of acid and again dissolved in water, were precipitated by *arsenite* of potash. The precipitate of arsenite of lead, which was at first light and flocculent, easily separated by boiling, and when dried weighed 391.26, but on being ignited gave out 6.65 of water and 16.51 of uncombined arsenious acid. The neutral salt remaining weighed 368.1.

A similar experiment gave arsenite of lead in the proportion of 368.8. Hence the composition of arsenite of lead, taking the former estimate, is

Arsenious acid .	45.667	—	100.000
Sub-oxyd of lead .	54.333	—	118.977
	100.000	—	218.977

Sub-oxyd of lead was found from very careful experiments to contain 7.15 per cent. of oxygen, and therefore the 118.977 contain 8.5068 oxygen. Hence the 100. of arsenious acid must contain some proportion of oxygen, which is a simple multiple of 8.5068, and as three times this quantity very nearly agrees with the experiments of Proust, arsenious acid is assumed to be composed of,

Arsenic . .	74.48	—	100.000
Oxygen . .	25.52	—	34.263
	100.00	—	134.263

The composition of the arsenic acid is also deduced from its combination with lead.

100 parts of arseniat of lead were dissolved in nitric acid, and precipitated by sulphat of ammonia. The supernatant liquor was evaporated to dryness to expel the excess of nitric acid, and the soluble portion was again dissolved in water and compleatly neutralized by ammonia. This separated a little sulphat of lead which was added to the other portion that remained insoluble in water. The whole sulphat of lead thus obtained was 95.59. A second experiment gave nearly similar results. This quantity of sulphat of lead much exceeded that obtained by Klaproth and Rose, by the simple addition of sulphat of ammonia to arseniat of lead in nitric acid, but professor Berzelius shews that these eminent chemists were not aware of the solubility of a portion of the sulphat of lead in the excess of acid.

Hence arseniate of lead consists of,

Arsenic acid .	29.6317	—	100.0
Sub-oxyd of lead	70.3683	—	237.5
	100.0000	—	337.5

The 237.3 of sub-oxyd of lead contain 16.981 of oxygen. Hence the composition of 100. parts of arsenic acid (according to the rules before laid down) must contain such a portion of oxygen as is produced by a simple multiplication of 16.981, and at the same time will afford such a proportion between the metal and the oxygen as will give an increase of oxygen upon 100. parts of the metal, in a simple (or nearly simple) ratio to the oxygen

[a] An. Chim. tom. 80. p. 9.

of the arsenious acid which is 34.263. These conditions will be fulfilled (making a reasonable allowance for errors) by taking the oxygen in 100. parts of arsenic acid as double that of the sub-oxyd of lead with which it is saturated, that is, $16.981 \times 2 = 33.962$.

Arsenic acid will therefore contain,

Arsenic	66.038	—	100
Oxygen	33.962	—	51.428
	100.000	—	151.428

And as the arsenious acid contains 34.263 oxygen to 100. of metal, the arsenic acid will contain to the same quantity of metal 1½ times $34.263 = 51.3945$, within a very small difference.

It has been already mentioned, under the article *affinity*, that wherever the ratio between two portions of the same substance that unite to another substance is expressed by a fraction (as 1½) there is reason to suppose some *minimum* of combination which will convert these fractional numbers to integers. This in the present instance will be produced by assuming the *minimum* of oxydation of arsenic, as either half or a quarter of that of the arsenious acid. It is well known that when metallic arsenic is exposed to the air it loses its lustre and becomes covered with a blackish brown powder. The author exposed 200. parts of metallic arsenic for two months to the air, at the end of which time it entirely fell into a bulky black powder. The increase of weight in that time was 16.2, and in another month the further increase was only 0.75, being in all 16.95, or in the proportion of 8.475 oxygen to 100. of metal, and $8.475 \times 6 = 50.85$, which does not much differ from 51.428, the highest term of oxygenation. Hence it is probable that the arsenious acid is 4 times the *minimum* of oxygenation, and the arsenic acid 6 times.

The *Arsenite of Lead* mentioned above has the following properties: when dry it is white, and by friction it becomes apparently even more electric than sulphur. When melted it is transparent, and remains so after cooling and then becomes yellowish, but of a dark green if any copper is present. Arsenite of lead kept at a red heat gives out arsenious acid, and is gradually changed to arseniate of lead.

Arsenicated Hydrogen.

Under the article *Alkaline Bases* in this appendix we have mentioned the alloy of potassium and arsenic, and the production of arsenicated hydrogen by adding water to this alloy. It was there found that when 100 parts of arsenicated hydrogen are kept in contact with melted tin, the latter extracts all the arsenic and then the hydrogen expands to 140 parts. *(See the above article.)*

ASPARAGUS.

The juice of this plant has been examined with much care and skill by M. Robriquet.* A quantity of asparagus was first bruised and the juice extracted by pressure, and passed through a coarse cloth, leaving a fecula behind. The juice in this state had a strong unpleasant smell, and was a dirty yellow colour inclining to green. The fecula, treated by boiling alcohol, only partially dissolved, and the insoluble portion examined in various ways strongly resembled animal gluten, in drying to a horny mass which by combustion gave much ammonia. The part soluble in hot alcohol deposited on cooling a substance a good deal like wax; whilst the supernatant solution contained a species of resin.

The filtered recent asparagus juice was sensibly acid and reddened litmus. After boiling, to separate some remaining flocculi of albumen, it was evaporated nearly to dryness, and then digested with alcohol, and the part untouched by this agent was dissolved in water. The alcoholic solution gave a very slight precipitate with acetite of lead, and this metallic precipitate was not again soluble in distilled vinegar, thus shewing that the acid of the asparagus-juice was not the malic. Another portion of the juice was assayed by distillation with sulphuric acid, and a quantity of acetic acid united with potash was obtained. Still the acid of the juice was not clearly made out, and it was afterwards analyzed with great attention. To obtain it pure the expressed juice of the plant was first coagulated by heat, and the clear liquor filtered. Into this liquor was poured acetite of lead as long as any precipitate formed, and this last when well washed was digested with a third of its weight of sulphuric acid diluted with three parts of water, and moderately heated. The sulphat of lead thus formed remained at the bottom, and the clear supernatant liquor was evaporated to an extractive consistence, and treated with alcohol twice successively (excluding a little insoluble matter each time) till a clear solution in the spirit was obtained. This acid was brownish, had a very sour taste mixed with some unpleasant flavour particularly when heated, and gave soluble salts with the alkalies and insoluble

* An. Chim. tom. 55.

ones with the earths. It decomposed the earthy acetites by simple affinity, and also many metallic salts, particularly those of iron, copper and lead, and the salt produced by its mixture with acetite of lead was in the form of white flocculi *insoluble* in distilled vinegar. In this last property it differed decisively from the malic acid, and also in decomposing the sulphats and acetites of iron and copper. To ascertain the nature of this acid of asparagus-juice it was precipitated by lime-water, and the washed precipitate calcined in a silver crucible till all the carbonaceous matter had disappeared, and a grey calcareous salt remained insoluble in water. This was boiled and dissolved in distilled vinegar and precipitated unaltered by ammonia, and then was found to be *phosphat of lime*.

To prove still further that this supposed peculiar acid is the phosphoric, its combination with lead (made by precipitating acetite of lead) was fused with the blow-pipe, and the button assumed on cooling that polyhedral form which is so characteristic of *phosphat of lead*.

Asparagus-juice does however contain some peculiar substances. A quantity of the juice was concentrated and left for a considerable time to itself in M. Vanquelin's laboratory. After a while a good many crystals formed in the liquor, obviously of two distinct kinds, which were examined by Messrs. Vauquelin and Robriquet.[b]

One of these (which indeed had before been noticed by M. Robriquet) had the following properties:

When obtained pure by repeated crystallization it assumes the form of rhomboidal prisms. It is quite white, moderately soluble in water, and neither acid nor alkaline; infusion of galls, acetite of lead, oxalat of ammonia, muriat of barytes, and hydro-sulphuret of barytes, produce no change in it: it is insoluble in alcohol. It contains neither ammonia nor earth: when ignited *per se* in a platina crucible, it swells up and exhales pungent vapours, and leaves a bulky coal but absolutely insipid, and the ash is not in the least degree alkaline. Nitric acid decomposes this salt and produces a yellow bitter liquor containing much ammonia formed in the process.

This salt therefore seems at present to be a peculiar crystallizable substance containing none of the known acids, alkalies, earths, or other salifiable bases.

The other crystals formed in the asparagus liquor were equally white, but soft and imperfectly crystallised in fine needles having a sensibly saccharine taste, like that of manna. It has not been further examined.

AUGITE.

In addition to the analysis of the Volcanic Augite from Etna by Vauquelin, already cited, we now have analyses of the Augite of Frascati,[c] and of Giuliana[d] in Sicily by Klaproth.

Fras.		Giul.	
48.	—	55.	silex
24.	—	10.	lime
8.75	—	1.75	magnesia
5.	—	16.5	alumine
12.	—	13.75	oxyd of iron
1.	—	—	oxyd of manganese
a trace	—	—	potash
—	—	1.5	water
98.75		98.5	

The Norwegian Augite has also been analyzed by Simon and Roux[e] with the following results.

Simon		Roux	
50.25	—	45.	silex
25.5	—	30.5	lime
3.5	—	3.	alumine
7.	—	—	magnesia
10.5	—	16.	oxyd of iron
2.25	—	5.	oxyd of manganese
0.5	—	—	water
a trace	—	—	chrome
99.5		99.5	

On examining however the details of the analysis by M. Roux, it is manifest that he failed to precipitate the whole of the alumine, and that the whole of the magnesia was left in the lime.

Var. 1. Coccolite, *Korniger Augit, Karsten*.

Its colour is a deep green; it presents an assemblage of slightly coherent granular concretions of various sizes up to that of a small pea, several of which resemble crystals with their solid angles worn off, and M. Hauy, by mechanical division, has actually reduced them to tetrahedral prisms. Internally this mineral is shining with a vitreous lustre; its fracture is foliated; it is translucent, scratches glass, and gives a few sparks with steel. Sp. gr. 3.3.

It is infusible by the blowpipe without ad-

[b] An. Chim. tom. 55. [c] An. Chim. lxvii. 225. [d] Klapr. Dict. de Chim. [e] Journ. de Mines.

dition; with soda it forms an olive green slaggy glass, and with borax a pale yellow semitransparent glass. It has been analyzed by Vauquelin, and appears to consist of

50.	silex
24.	lime
10.	magnesia
1.5	alumine
7.	oxyd of iron
3.	oxyd of manganese
95.5	
4.5	loss

It occurs in the iron mines of Sudermania; and of Arendahl in Norway.

Var. 2. *Sahlite.* Malacolite, *D'Andrada.*

Its colour is pale greyish green; its external lustre is vitreous approaching to waxy; it is translucent; it scratches glass slightly, but gives no sparks with steel, and is easily frangible. Fracture shining and strait lamellar with a triple cleavage. It is generally in the form of coarsely granular distinct concretions, but also occurs massive with a broad lamellar fracture, or crystallized in rectangular parallelepipeds slightly bevilled on their lateral edges, or in prisms terminated by convex planes. Sp. gr. 3.23.

It is infusible before the blowpipe without addition.

It occurs in Sweden at the silver mines of Sahla; and at Buoen in Norway.

Its component parts, according to an analysis by Vauquelin, are

53.	silex
20.	lime
19.	magnesia
3.	alumine
4.	oxyds of iron and of manganese
99.	
1.	loss.

To this variety, on the authority of M. Hauy, are also to be referred the Mussite and Alalite of M. Bonvoisin, of which M. Hauy had once formed a new species under the name Diopside.[a]

Its colour is greenish or yellowish white: it occurs crystallized in tetrahedral and dodecahedral prisms, or in deeply striated sub-cylindrical grains, or massive with a lamellar fracture. It scarcely scratches glass, and is fusible before the blowpipe into a greyish mass. It is composed, according to Laugier, of

57.	silex
16.5	lime
18.25	magnesia
6.	oxyds of iron and of manganese
97.75	
2.25	loss.

The Mussite occurs in the Commune of Balme-de-Mussa, Department of the Po, in a vein accompanied by granular carbonate of lime.

The Alalite occurs near the village of Ala, in the mountain of Ciarmetta, in a vein accompanied by garnets.

AUTOMOLITE. *Spinelle zincifère, H.*

This substance occurs only crystallized. Its primitive form is the regular octohedron, besides which it presents the transposed octohedron. The crystals are for the most part very small, rarely equalling in size a small nut. Its specific gravity is 4.69 (4.26 Ekeberg). It scratches quartz. Its colour is a deep bluish-green: the entire crystals are opake, but in thin fragments it is more or less semi-transparent. Its fracture is lamellar, parallel to the faces of the crystal, but in other directions is uneven and scaly with a vitreous lustre.

Before the blowpipe it neither melts nor undergoes any change of colour. With phosphate of soda it runs into a clear colourless bead.

It was first analyzed by Ekeberg, and afterwards by Vauquelin, with the following results.

Ekeb.		Vauq.	
60.	—	42.	alumine
4.	—	4.	silex
24.	—	28.	oxyd of zinc
9.	—	5.	oxyd of iron
0.	—	17.	sulphur
0.	—	4.	portion of the mineral remaining unaltered.
97.		100.	

It occurs at Fahlun in Sweden.

It was at first supposed to be corundum mixed with zinc, but the prevailing opinion at present is that it is spinelle pleonaste loaded with blende.

AZOTE WITH OXYGEN, *Compounds of.* The specific gravity of azotic gas is to that of hydrogen, as 13 to 1.[b] 100 cubical inches of it at a mean temperature and pressure, weigh between 29. and 30. grains.

There are at least three specific compounds of azote and oxygen; viz. Nitrous Oxyd, Nitrous Gas, and Nitrous Acid Gas.

[a] Journ. des Mines, No. 115.

[b] Davy's Elements.

Nitrous Oxyd. The specific gravity of this gas is to that of hydrogen as 21. to 1; and 100. cubic inches weigh between 48 and 49 grains. When one cubic inch of nitrous oxyd is mixed with the same quantity of hydrogen and exploded by the electric spark, water is formed, and the only residue is one cubic inch of azote. Now as one cubic inch of hydrogen requires half a cubic inch of oxygen to become water, it follows that one cubic inch of nitrous oxyd contains one cubic inch of azote and half a cubic inch of oxygen, condensed into the space of a single cubic inch.

In like manner, if dry charcoal be ignited in one cubic inch of nitrous oxyd, the products are half a cubic inch of carbonic acid and one cubic inch of azote. Hence, as oxygen neither gains nor loses in bulk by its conversion into carbonic acid, the composition of nitrous oxyd s found, as before, to be two volumes of azote and one of oxygen, condensed into the space of two volumes. Hence too it consists, by weight, of 26 of azote and 15 of oxygen.

Nitrous Gas. Its specific gravity is to that of hydrogen as 14 to 1; and 100 cubic inches weigh about 32 grains. When several metals, such as arsenic, zinc, or potassium, are heated in nitrous gas, it oxydates them and affords half its volume of azote. If charcoal is ignited in two cubic inches of nitrous gas, the products are one cubic inch of carbonic acid and one of azote. Hence as oxygen gas neither expands nor contracts by conversion into carbonic acid gas, nitrous gas consists of equal volumes of azote and oxygen not condensed by their chemical union; or it contains (by weight) 13 parts of azote to 15 of oxygen. When two cubic inches of nitrous gas are exposed to the action of muriat of tin, or sulphuretted alkali, part of the oxygen of the gas is absorbed, and one cubic inch of nitrous oxyd is left, which exactly harmonizes with their relative proportions of oxygen and azote; for one cubic inch of nitrous oxyd contains, as already mentioned, one cubic inch of azote and half a cubic inch of oxygen; and therefore the portion of oxygen extracted by the sulphuret is exactly half a cubic inch of oxygen.

Nitrous Acid Gas. When oxygen and nitrous gas are mixed together, red fumes of *nitrous acid gas* are produced, and a condensation of the bulk of the gasses takes place. If the experiment be made over water, a rapid and total absorption takes place, and the water becomes acidulous. Much difference of opinion still exists as to the respective proportions in which nitrous gas and oxygen unite, nor is it very easy to make accurate experiments, since the acid gas is absorbed both by water and mercury.

According to Sir H. Davy, when two volumes of nitrous gas and one volume of oxygen, both previously dried, are mixed together in a vessel exhausted of air, they become condensed to half their volume, and form a deep orange-coloured gas, which is nitrous acid gas. Calculating from the condensation, the specific gravity of this gas must be to that of hydrogen as about 28. to 1; and 100 grains of it must weigh 65.3 grains. When water is admitted to this gas there is a rapid absorption, and the water gains a tint of green. This proportion of two volumes of nitrous gas to one volume of oxygen is the highest in oxygenation that can be produced as a pure and distinct gaseous body; for when the oxygen is actually mixed in greater proportion, the condensation is such as only to indicate the formation of the above nitrous acid gas, with an excess of uncombined oxygen. The same happens when water is admitted, the acid gas absorbed retaining no greater a proportion of oxygen than when in a gasseous state. But on the other hand, when this nitrous acid gas is absorbed by an alkaline base, a portion of nitrous gas is always evolved, leaving the remainder in a state of a higher relative oxygenation than gasseous nitric acid. This the author concludes from many experiments to be in the proportion of 2 volumes of nitrous gas and 1½ of oxygen, and this forms the *pale nitric acid* as it exists in solution in water, or as the acid part of the alkaline, earthy, and metallic nitrats. Nitric acid therefore, according to this opinion, when once obtained from the decomposition of the nitrats can exist unchanged in solution in water; though water alone cannot condense from its gasseous state a mixture of two volumes of nitrous gas and 1½ of oxygen, which is here given as the composition of nitric acid. This liquid acid again may be made to absorb different quantities of nitrous gas, when it becomes yellow, orange, blue, and finally blueish-green, when saturated with nitrous gas.

It has been mentioned that oxygen and nitrous gas unite in different proportions, and these are in a good measure regulated by the quantities of each gas employed, and the diameter of the vessel in which they are mixed. Mr. Dalton gives the following interesting re-

sults of his own experience on this subject.* When two measures of nitrous gas are put to one measure of oxygen gas in a tube one-third of an inch in diameter and five inches in length, standing over water, as soon as the diminution has apparently ceased, which will be in half a minute, if the residuary gas is transferred into another tube, it will be found that one measure of oxygen and 1.8 of nitrous gas have disappeared.

When 4 measures of oxygen are put to 1.3 of nitrous gas in a tube two-tenths of an inch in diameter and ten inches long so as to fill it, it will be found that 1 measure of oxygen will combine with 1.3 of nitrous gas in four or five minutes.

When 1 measure of oxygen and 5 of nitrous gas are mixed together so as to form a thin stratum of air not more than ⅛th of an inch in depth (as under a common tumbler) the oxygen will take up from 3 to 3½ measures of nitrous gas in a moment, without any agitation. If equal measures are mixed, then 1 oxygen takes about 2.2 nitrous gas.

Thus it appears that these two gasses will unite in a great variety of proportions, according to the relative quantity of either gas employed, and the suddenness of their union. But according to Mr. Dalton, there is however a definite *maximum* and *minimum* of saturation, which includes all the other proportions. The *maximum* of oxygenation actually observed is that in which 1 measure of oxygen combines with 1.3 of nitrous gas; and the *minimum* is that of 1 measure of oxygen to 3.6 of nitrous gas; but as the actual maximum does not harmonize with any definite proportion, Mr. D. assumes hypothetically the real *maximum* to be 1 of oxygen with .9 of nitrous gas, to which he gives the term *oxynitric* acid. The constitution of nitric acid he infers from other observations to be 1 measure of oxygen to 1.8 of nitrous gas. Hence all the compounds of nitrous gas and oxygen will be thus expressed:

measure		measures		
1	oxygen with	.9	nitrous gas form	oxynitric acid
1	———	1.8	———	nitric acid
1	———	3.6	———	nitrous acid

And all the intermediate degrees of saturation are considered as mixtures of two or more of the above compounds.

One of the most important considerations relative to nitric acid is the determination of the quantity of real acid in a watery solution of a given specific gravity. The temperature of ebullition of nitric acid of different densities varies in a very singular manner. When weak nitric acid is boiled or distilled, the weakest portion comes over first; but when the acid is concentrated, the strongest portion comes over first, as observed by Dr. R. Perceval (*see Chim. Dict. art. Nitric acid*). From these facts, Mr. Dalton inferred that an acid of some one strength, and only one, was incapable of any change of strength by distillation, so that when a portion of this was distilled, the distilled part and the residue would have the same specific gravity. It was desirable to find the actual strength of this acid, as these circumstances shew a nice adjustment of affinities between the acid and the water; and this acid Mr. Dalton has found by many experiments to be of the specific gravity of 1.42. The boiling temperature of this acid is higher than that of any other nitric acid, stronger or weaker, being 248°, which indeed is the immediate reason of the reduction of strength of all the other nitric acids to that of 1.42 when submitted to gradual distillation; and of the stronger acids parting with the portion above 1.42 and the weaker acids with that below this standard. Hence the continued boiling of any nitric acid tends to bring the portion in the retort to the specific gravity of 1.42, and to raise the temperature to 248°. Mr. Dalton calculates this acid of 1.42 to be composed of 2 atoms of water to 1 atom of real acid. The acid of 1 of real acid to 4 of water has the specific gravity of 1.30, and is remarkable for freezing the most easily of all, namely at —2°. according to Mr. Cavendish.

With respect to the quantity of real acid in a solution of given specific gravity, Mr. Dalton follows the method employed by Kirwan, assuming that fused nitre consists of 47.5 per cent. by weight of real acid and 52.5 of potash. Mr. Dalton's estimate of the real acid of different mixtures of nitric acid and water, agrees very nearly with those of Mr. Kirwan, but Mr. D. has given the important addition of the boiling temperature of each. The following is his table of the quantity of real acid in 100 parts of liquid nitric acid at the temperature of 60°.

* New System, part ii. p. 327.

Acid per cent. by weight.	Acid per cent. by measure.	Specific gravity.	Boiling point.
100	175?	1.75?	30°?
82.7	134	1.62	100°
72.5	112	1.54	175°
68	102	1.50	210°
58.4	84.7	1.45	240°
54.4	77.2	1.42	248°
51.2	71.7	1.40	247°
44.3	59.8	1.35	242°
37.4	48.6	1.30	236°
32.3	40.7	1.26	232°
28.5	34.8	1.22	229°
25.4	30.5	1.20	226°
23	27.1	1.18	223°
21	24.6	1.17	221°
19.3	22.4	1.16	220°
17.8	20.5	1.15	219°
16.6	18.9	1.14	219°

M. Gay Lussac,[d] in repeating Mr. Dalton's experiments on the different proportions of oxygen absorbed by nitrous gas according to the circumstances of the experiment, has endeavoured to reduce all the definite combinations of azote and oxygen to very simple numbers, estimating the gasses by measure.

Nitrous gas is composed of equal volumes of azote and oxygen, which unite without condensation; and the author considers nitric acid as composed of 200 measures of nitrous gas and 100 measures of oxygen, or (what amounts to the same) it consists of 100 measures of azote to 200 of oxygen. The intermediate term of saturation is that which constitutes *nitrous acid gas*, and which when absorbed by water gives the *liquid nitrous acid*, the acid part of the *nitrites*. The author finds, agreeably to Mr. Dalton's experiments, that the production of this intermediate acid depends on the circumstances of the experiment and the proportions of each gas employed. If 200 measures of nitrous gas are put into a narrow tube over water, and 200 measures of oxygen are added, or if this order is reversed, and the oxygen added first, 300 measures will disappear and 100 measures of oxygen will remain unaltered. The water that has absorbed these 300 measures will be a solution of *nitric* acid, and with potash will form common nitre. Therefore nitric acid contains 2 parts by measure of nitrous gas to one of oxygen. But if the oxygen be not in excess, if for example 100 measures of oxygen be added to 400 measures of nitrous gas, the entire absorption will be 400 measures, and 100 measures of nitrous gas will remain. The water that has absorbed these 400 measures will now be *nitrous* acid, and with potash will form small needled crystals of *nitrite of potash*, which give out copious red fumes on the addition of any strong acid. To make this experiment correctly it should be in a wide vessel and without agitation, so that the water in absorbing the nitrous acid gas may not also absorb a portion of the residuary nitrous gas. *Nitrous* acid therefore is produced by the union of 300 measures of nitrous gas with 100 of oxygen; or (what amounts to the same) it consists of 150 measures of azote to 250 of oxygen. It is best made by dissolving nitrous acid gas in water, which becomes blue, green, and finally orange yellow, according to the strength of the acid and the quantity of gas absorbed. Hence it is that the orange yellow acid may be changed to the green, and the green to the blue, merely by proper dilution with water, which diminishes the relative strength of the acid in a given quantity.

The liquid nitrous acid is also made by passing nitrous acid gas into liquid *nitric* acid, which then becomes blue, green, or yellow orange, according to the concentration of the nitric acid.

M. Gay Lussac gives the following estimate of the composition of the oxyds of azote, viz.

Nitrous oxyd consists of 100 measures of azote with 50 measures of oxygen; or, by weight, of 63.72 of azote and 36.28 oxygen.

Nitrous gas consits of equal measures of azote and oxygen; or, by weight, of 46.757 of azote and 53.243 of oxygen.

Nitrous acid gas consists of 300 measures of nitrous gas to 100 measures of oxygen; or, by weight, of 34.507 of azote and 65.493 of oxygen.

Nitric acid consists of 100 measures of azote to 200 measures of oxygen, or of 200 measures of nitrous gas to 100 measures of oxygen; or, by weight, of 30.512 of azote to 69.488 of oxygen.

AZOTIZED OXYMURIATIC ACID, or Azotized Chlorine. (*Acide Muriatique oxiazoté.*)

Under this term we shall describe a new and most remarkable compound of azote and oxymuriatic acid, which appears to be the most violently detonating substance hitherto known. The first notice of the fact of this discovery published in this country is (we believe) con-

[d] Mem. d'Arcueil, tom. 2.

tained in the extract of a letter published by Sir H. Davy,[a] which announces the discovery of a compound of azote and chlorine appearing as an oil heavier than water, that detonates with all the violence of the fulminating metals by the mere heat of the hand, separating thereby in the gasseous form the two elements of which it is composed, evolving much heat and light. The writer also adds that this dangerous property had cost to the discoverer both an eye and a finger.

With this obscure hint of the nature of this substance, added to the recollection of the accidental formation of an oil by passing chlorine gas through nitrat of ammonia suggested by Mr. Children, Sir H. Davy has been enabled to produce this oily detonating compound, which indeed is a very simple process, and, as we are informed in the memoir on the subject, had nearly cost him the same unfortunate sacrifice of an eye as to the first discoverer (M. Dulong) in the attempt to become more familiar with the properties of this formidable compound.

M. Dulong has since made known all the particulars of this discovery in a paper lately read to the French Institute, of which a general abstract is given by Messrs. Thenard and Berthollet.[b]

From this and Sir H. Davy's memoir we learn the following particulars. Azote and oxymuriatic gas have no known action on each other when in the gasseous form, but when oxymuriatic gas is passed through a solution of the nitrat of ammonia, the oxalat, or many other ammoniacal salts, it is rapidly absorbed and a film collects on the surface, which is soon resolved into distinct drops of a yellowish oil that sinks to the bottom of the liquid, and is the detonating compound in question. A weak solution of pure ammonia will answer as well as the neutral ammoniacal salt. A temperature of about 40° or 50° answers the best for its production. Sir H. Davy obtained it immediately by *shaking* in a phial a saturated solution of nitrated ammonia with about six cubic inches of chlorine, a mode of operating which appears attended with extreme hazard, for even when a large quantity of the gas was merely passed through a Woulfe's apparatus charged with the different ammoniacal solutions, the whole exploded violently and shattered the apparatus to pieces.

This detonating oil is yellowish, but quite transparent and highly liquid. Its smell is very nauseous, resembling that of the compound of carbonic oxyd and chlorine. It evaporates rapidly but silently when exposed to the air at a common temperature, but when slightly warmed it explodes vehemently, insomuch that it is dangerous to warm in any glass vessel a globule of the oil no bigger than a grain of mustard seed. When this oil merely touches many combustible matters, even without increasing the temperature, it explodes very violently, so as generally to shatter any glass vessel. This is the case when a globule of it is thrown into olive oil, turpentine, or naphtha. But with alcohol it only loses gradually its explosive property and becomes a white oily matter. When a particle of this oil touches phosphorus, or phosphorized alcohol and ether, it explodes with equal violence. It has no effect on muriatic or sulphuric acid, zinc, tinfoil or sulphur. M. Dulong attempted to analyze it by adding it, and the liquor in which it was formed, to a vessel containing copper filings. Muriated oxyd of copper was produced and azotic gas given out. It seems therefore to be without doubt a compound of chlorine and azote, but its unmanageable properties make its analysis an affair of difficulty and some danger.

B

BARIUM. Barytes.

The basis of the earth barytes was first obtained by the eminent discoverer of the alkaline bases in the following way:[c] pure barytes was made into a paste with water, and a small cavity made in it to receive a globule of mercury, the barytes was laid on a slip of platina which was made positive in a voltaic battery, and the globule of mercury was rendered negative. In this state the barytes was deprived of oxygen, and its base, *Barium*, was obtained amalgamated with the mercury, from which it was separated by evaporating the mercury. Barium thus procured is of a dark grey colour, with a low metallic lustre, and heavier than sulphuric acid. When thrown into water it effervesces, hydrogen is given off from one portion of the decomposed water whilst its oxygen unites with the barium, and barytes is reproduced and dissolves in the water.

Sir H. Davy estimates the elements of barytes to be about 89.7 per cent. of barium, and 10.3 of oxygen.

Barytes is the first oxyd of barium. Its

[a] Phil. Trans. for 1813. [b] Ann. de Chim. tom. lxxxvi. p. 37. [c] Davy's Elements.

properties have been fully described in our original article, and the difference between the pure barytes obtained from the nitrat and that procured from the crystals of barytes formed by solution in water, has been mentioned in the article *Alkali* in this appendix.

Peroxyd of Barium. According to the experiments of Messrs. Gay Lussac and Thenard, barytes can absorb oxygen, and thus produce an oxyd of barium of a higher state of oxydation than barytes.[b] For this purpose some dry oxygen gas was passed into a glass tube over mercury, and along with it some fragments of pure barytes arising from the calcined nitrat On applying the heat of a lamp, the oxygen was very rapidly absorbed, and the barytes appeared as if glazed on its surface, and became greyer.

The glass was then filled with hydrogen and heated as before. The hydrogen was absorbed in large quantity, and sparks were seen to proceed from the barytes. No water was vaporized, so that all of this fluid, which must have been produced by this absorption of hydrogen, was absorbed by the barytes, which then became very fusible.

The experiment was repeated with similar success with barytes prepared by calcining the carbonat of barytes with lamp-black in an intense heat; so that the effect could not have been produced in the first instance by any undecomposed nitric acid.

BENZOIN. Benzoic Acid. Benzoats.

We have to mention some additional facts relative to this resin and its products, which are among the most interesting of this class of vegetable substances.[a]

When benzoin is gradually heated in moderately dilute nitric acid, it is dissolved into a light yellow liquid, which on cooling gradually deposits nearly the whole of the benzoic acid, whilst the resin appears to remain dissolved. This solution is totally decomposed by water.

Sulphuric acid dissolves benzoin into a deep red liquid, but carbonizes a portion of it. The solution gives a lilac precipitate with water. Acetic acid dissolves this resin even in the cold. When saturated by boiling, much benzoic acid separates on cooling.

When these acids are added to the solution of benzoin in alcohol, a precipitate is formed (with all but the nitric) which is probably a compound of the resin and acid, and an excess of the same acid generally redissolves a part of this precipitate. Nitric acid on the other hand does not render the alcoholic solution turbid, but gives it a dark red colour, so that this acid seems to have a greater solvent power over the resin of benzoin.

Benzoic Acid. Scarcely two thirds of the whole acid contained in benzoin is procured by mere sublimation. Scheele's process (mentioned in our original article) gives the purest acid.

Some German chemists have also employed carbonat of potash or soda, as an intermede for obtaining this acid. Benzoin, boiled repeatedly with about a tenth of its weight of carbonat of soda and sufficient water, the resin being taken out two or three times and triturated, and again boiled with the same liquor, yields at last nearly the whole of its acid to the soda, and the solution of benzoat of soda deposits its acid on adding the sulphuric acid.

Benzoic acid is soluble in most of the acids, but separable from them by dilution with water.

A singular fluid compound of benzoic acid and camphor is mentioned by Mr. Gowar,[b] to be produced by adding a definite quantity of water to a solution of both these substances in alcohol.

Twenty grains of benzoic acid and as much camphor dissolved in half an ounce of common alcohol, and then diluted with as much water, gradually separates into two liquids, both of which are quite transparent if the acid is free from resin, but yellowish if otherwise.

Both the upper and lower liquids appear to be compounds of alcohol, water, benzoic acid and camphor. The lower, which has an oily appearance, is strongly acid and aromatic, and by evaporation forms crystals apparently composed of benzoic acid and camphor. Cold water added to this liquid immediately decomposes it, the benzoic acid being precipitated in the form of shining crystals, and the camphor floating on the top. The upper fluid on standing for a time, sometimes deposits large crystals floating upon the lower stratum, which are chiefly benzoic acid, but altered from its usual crystallized form, probably by the presence of some camphor.

It requires pretty exactly the above mentioned proportion of benzoic acid, camphor, alcohol and water, to produce this singular separation into two distinct solutions, for when more of the spirituous menstruum is used, the whole remains as one uniform solution, and when a greater proportion of water is employed, much of the camphor and part of the acid separate.

Mr. Bucholz has examined some of the leading properties of the benzoic acid, with a view

[b] Recherches, tom. I. p. 169.

[a] Brande in Phil. Journ. vol. x.

[b] Phil. Journ. vol. xxviii. p. 28.

of comparing them with the camphoric acid, some chemists having considered these two acids as nearly identical. The properties of the *Camphoric Acid* will be given under that article; those of the benzoic are the following:

Ten grains of benzoic acid were mixed with 500 grains of distilled water, and shaken in a phial for half an hour. The whole liquid was passed through a filter, the weight of which when dry was previously known, and after again drying there was found an addition of 7½ grains of weight produced by the undissolved acid. Hence Benzoic acid requires 200 times its weight of cold water for perfect solution. On the other hand it requires only 24 parts of boiling water, so that by far the greater part of the acid must again separate on cooling.

An hundred grains of cold alcohol dissolve by agitation about 56 grains of benzoic acid; and boiling alcohol dissolves nearly its own weight of the acid.

Benzoat of Lime. Benzoic acid boiled with carbonat of lime and water is gradually neutralized; and 50 grains of the acid require in this way about 20 grains of the calcareous earth, the pure lime of which is about 13 grains. The solution when much reduced by evaporation gives on cooling a number of shining silky needled crystals, often radiating from a common center; their taste is sweetish and somewhat earthy.

Though this benzoat of lime is prepared with the purest acid, and is perfectly white, when heated by itself in a close vessel it gives a liquid empyreumatic oil, smelling of the resin of benzoin. Benzoat of lime requires 20 times its weight of cold water for perfect solution.

Benzoat of Potash. This salt crystallizes when the acid is slightly in excess, forming small needles which require ten parts of cold water for solution. The neutralized salt is much more soluble and deliquescent.

It is to be observed that when most of the neutral benzoats are evaporated, part of the acid flies off, leaving the salt with a slight excess of base. This however is not the case with the benzoat of ammonia, the alkali being full as volatile as the acid. This property is of some importance as it gives a reason for a preference of the benzoat of ammonia in a very important use in analytical chemistry, to which it has lately been applied by Professor Berzelius.

This eminent chemist has found that the benzoic acid may be applied to the separation of iron from manganese, with equal success with the *Succinic*, and it has the advantage of being much cheaper and more easily obtained. It is necessary for this purpose that the solution containing the mixed oxyds should be previously neutralized with accuracy, and then the benzoat of ammonia may be added as long as any precipitate falls down. This precipitate is merely benzoat of iron, and all the manganese remains in solution.

Not only will this salt separate iron from manganese, but as M. Hisinger has observed, it will equally separate it from all earthy salts, and from nickel, cobalt and many other metals, none of which are precipitated by the benzoat when properly applied.

(This will be further described in this appendix under the article IRON.)

BILDSTEIN.

From a recent analysis of this substance by Vauquelin,[a] it appears to be composed of

56.	Silex
29.	Alumine
2.	Lime
7.	Potash
1.	Oxide of Iron
5.	Water
100	

It is interesting to observe, that in this mineral the character of unctuosity is by no means indicative of the presence of magnesia. The analogy also, as to chemical composition, between bildstein, mica, and felspar, is deserving of notice.

BILE.

This important fluid has been analyzed by Thenard,[a] a very skilful chemist, who has discovered in the bile of some animals what he considers as a new animal principle, to which he gives the name of *Picromel*, on account of its sweet and pungent taste.

The experiments on ox-gall are the following. A quantity of it was distilled to dryness in a retort, by which it lost from $\frac{7}{8}$ to $\frac{8}{9}$ of its weight of mere water a little flavoured. The dry yellow residue was calcined carefully in a platina or silver crucible kept scarcely at a cherry-red, by which it gave 22 per cent. of carbonaceous residue containing soda, common salt, phosphat and sulphat of soda, and phosphat of lime.

The uncombined soda amounted to no more than $\frac{1}{200}$ of the original gall, which appeared much too small a quantity to be the intermede whereby the resin of this bile might be held in solution. Neither is the precipitate formed by acids at all equal to the whole of the solid

a Journ des Mines. No. lxxxviii. p. 247.

a Mem. d'Arceuil, tom. i.

matter which may be extracted from the bile, which is another reason for supposing some other substance besides soda which holds the resinous matter of bile in perfect solution. The analysis of ox-gall was thus conducted: A little nitric acid was first added, which precipitated a peculiar yellow matter along with a very little resin, which last was afterwards obtained pure by alcohol. The gall was filtered, and into it was poured a solution of sub-acetite of lead (made with 8 parts of common acetite and one of litharge) by which an insoluble compound of oxyd of lead and the resin of the gall fell down, (separable from each other by weak nitric acid) and the supernatant liquor was freed from the excess of the salt of lead by a current of sulphuretted hydrogen. The clear filtered liquor was evaporated to dryness, and gave the *Picromel* mixed with acetite of soda. The distinguishing properties of picromel, according to M. Thenard, are its pungent sweetish taste, and the great solvent power which it exercises over the resin of the bile; so that by adding again the due proportions of this resin, of picromel, of the yellow matter separable by nitric acid, and of soda, the author obtained an uniform liquid exactly resembling the original bile from which these substances had been extracted. Of 800 parts of ox-gall the author finds 700 of water, 24 of resin, 60½ of picromel, about 4 of yellow matter, and 4 of soda, and the rest salts of soda and lime.

Picromel dissolves both in water and in alcohol, does not crystallize, and forms a triple compound with resin and soda, highly soluble in water, and not decomposable by acids, alkalies, and earthy salts; but it is separated by some metallic salts.

The resin of bile is green, bitter, soluble in alcohol, and separable thence by water, and soluble in alkalies, and in some acids, but not in all.

It appears however in the author's second memoir on this subject, that the picromel is not so certainly obtained in the above method; for he says that if too much of the acetite of lead is added, the picromel itself is separated, so that it is necessary to assay the precipitate from time to time, and as soon as it becomes totally soluble in weak nitric acid, it will shew that all the resin has been separated, and that the picromel itself begins to precipitate.

M. Thenard gives the result of the analysis of the bile of different animals, and finds no picromel in human bile, this secretion containing chiefly water, albumen, a peculiar resin, soda, and some salts.

Professor Berzelius in his analysis of bile,[b] entirely denies the existence of this peculiar substance, *picromel*, as a distinct animal principle, and seems to consider merely the whole of the solid contents of the bile (the saline part excepted) as one peculiar albuminous substance, which partly precipitates in the form of a resin when some mineral acid is added; and therefore this supposed resin is a compound of the peculiar bitter albumen of bile with a small portion of the acid employed. This biliary matter is soluble in water, even without the assistance of alkali or of any other intermede; and it forms two compounds with some acids, one soluble, the other not so, and therefore precipitated, and in the form of a resin. But the acetous acid which gives soluble compounds with the albumen of blood does the same with biliary albumen, and hence no precipitate follows the addition of this acid to bile.

The biliary matter may be obtained pure in the following way: mix fresh bile with sulphuric acid diluted with 3 or 4 parts of water, a yellow precipitate whose nature is hardly known first appears and must be separated; then continue adding more of the acid as long as any thing falls down, decant the fluid part and edulcorate the remaining green resiniform substance. This, which is in fact a compound of biliary albumen and sulphuric acid, may be deprived of its acid either by digestion with carbonat of barytes and water, or by solution in alcohol, and digesting the liquid with carbonat of lime as long as it reddens litmus. The clear liquor then contains the pure biliary albumen, which is to be evaporated to dryness. This gives a green solution in water closely resembling the natural bile. The quantity of this biliary matter he estimates at $\frac{8}{100}$ of the whole bile.

BIRDLIME.

This substance has been commonly supposed to be analogous to vegetable gluten, like that of wheat, but it does not appear to have been analyzed with any care till Bouillon la Grange examined it, and he has found the following properties.[a]

The birdlime here employed was that of the inner bark of the holly, prepared by bruising the bark in a mortar, boiling it with water for four or five hours, throwing away the liquor, and putting the residue in earthen pots, and keeping it in a damp cellar till it was mouldy and viscous, moistening it now and then with water, and then washing it thoroughly with water to remove all heterogeneous matters.

[b] Medico-Chirurg. Transacts. vol. iii.

[a] Ann. Chim. tom. lvi.